JC14 Rec'd PCT/PTO 08 JAN 2002

FORM PTO-1390 REV. 2/01T U S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE **TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371**		ATTORNEY'S DOCKET NUMBER 08364.0032 Customer No.: 22,852 U.S. APPLICATION NO. (If known, see 37CFR1.5) 10/030240
INTERNATIONAL APPLICATION NO. **PCT/GB00/02668**	INTERNATIONAL FILING DATE **July 10, 2000**	PRIORITY DATE CLAIMED **July 8, 1999**

TITLE OF INVENTION: **SIGNALLING SYSTEM**

APPLICANTS FOR DO/EO/US: **1) Alan Edward GREEN, 2) Euan MORRISON, and 3) Michael REYNOLDS**

Applicants herewith submit to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☐ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (21) indicated below.
4. ☒ The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371 (c)(2)).
   - a. ☒ is attached hereto (required only if not communicated by the International Bureau.
   - b. ☒ has been communicated by the International Bureau.
   - c. ☐ is not required, as the application was filed with the United States Receiving Office (RO/US).
6. ☐ An English language translation of the International Application as filed (35 U.S.C. 371 (c)(2)).
   - a. ☐ is attached hereto.
   - b. ☐ has been previously submitted under 35 U.S.C. 154 (d)(4).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3)).
   - a. ☐ are attached hereto (required only if not communicated by the International Bureau).
   - b. ☐ have been communicated by the International Bureau.
   - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   - d. ☒ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371 (c)(3)).
9. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
10. ☒ The annexes of the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).

Items 11 to 20 below concern document(s) or information included:

11. ☒ Information Disclosure Statement under 37 CFR 1.97 and 1.98
12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A FIRST preliminary amendment.
14. ☐ A SECOND or SUBSEQUENT preliminary amendment.
15. ☐ A Substitute specification.
16. ☐ A change of power of attorney and/or address letter.
17. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821-1.825.
18. ☐ A second copy of the published international application under 35 U.S.C. 154 (d)(4).
19. ☐ A second copy of the English language translation of the international application 35 U.S.C. 154 (d)(4).
20. ☒ Other items or information:
    - a. ☒ Copy of cover page of International Publication No. WO 01/05069 A2.
    - b. ☐ Copy of Notification of Missing Requirements.

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U.S. APPLICATION NO (If known, see 37CFR 1.5) 10/030240	INTERNATIONAL APPLICATION NO. **PCT/GB00/02668**	ATTORNEY'S DOCKET NUMBER: 08364.0032

21. ☒ The following fees are submitted:

CALCULATIONS PTO USE ONLY

BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)):

Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO **$1040.00**

International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO **$890.00**

International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search fee (37 CFR 1.445(a)(2)) paid to USPTO **$740.00**

International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) **$710.00**

International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33 (1)-(4) **$100.00**

ENTER APPROPRIATE BASIC FEE AMOUNT =					$890.00	
Surcharge of $130.00 for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (e)).					$	
CLAIMS	NUMBER FILED		NUMBER EXTRA	RATE		
Total Claims	50	- 20 =	30	x $18.00	$540.00	
Independent Claims	6	-3 =	3	x $84.00	$252.00	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)				+$280.00	$	
TOTAL OF THE ABOVE CALCULATIONS =					$1682.00	
☐ Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by ½.					$	
SUBTOTAL =					$1682.00	
Processing fee of **$130.00** for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest priority date (37 CFR 1.492(f)).					$	
TOTAL NATIONAL FEE =					$1682.00	
Fee for recording the enclosed assignment (37 CFR 1.21 (h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). **$40.00** per property. +					$	
TOTAL FEES ENCLOSED =					$1682.00	
					Amount to be refunded:	$
					charged:	$

a. ☒ A check in the amount of $ 1682.00 to cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account No. ______ in the amount of $ ______ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 06-0916. A duplicate copy of this sheet is enclosed.

d. ☐ Fees are to be charged to a credit card. **WARNING:** Information on this form may become public. **Credit card information should not be included on this form.** Provide credit card information and authorization on PTO-2038.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137 (a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

Finnegan, Henderson, Farabow, Garrett & Dunner, L.L.P.
1300 I Street, N.W.
Washington, D.C. 20005-3315
EFC/FPD/sci
DATED: January 8, 2002

SIGNATURE

Ernest F. Chapman/25,961

NAME/REGISTRATION NO.

10/030240
JC13 Rec'd PCT/PTO 08 JAN 2002

PATENT
Attorney Docket No. 08364.0032
CUSTOMER NUMBER 22,852

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:

Alan Edward GREEN et al.

Serial No.: Not Yet Assigned

Filed: January 8, 2002

National Stage of International Application No. **PCT/GB00/02668**, under 35 U.S.C. 371, for **SIGNALLING SYSTEM**

Group Art Unit: Not Yet Assigned

Examiner: Not Yet Assigned

Assistant Commissioner for Patents
Washington, DC 20231

Sir:

PRELIMINARY AMENDMENT

Prior to examination, please amend the above-identified application as follows:

IN THE SPECIFICATION:

Please amend the specification as follows:

Page 1, after the title insert a new paragraph as follows:

--CROSS REFERENCE TO RELATED APPLICATIONS

This application is a national phase application based on international application number **PCT/GB00/02668**, filed on July 10, 2000, and claims the priority of British Patent Application Nos. 9916080.6, filed on July 8, 1999, and 9916422.0, filed on July 13, 1999.--

FINNEGAN
HENDERSON
FARABOW
GARRETT &
DUNNER LLP

1300 I Street, NW
Washington, DC 20005
202.408.4000
Fax 202.408.4400
www.finnegan.com

IN THE CLAIMS:

Please replace now pending claims 1-36 without prejudice or disclaimer and substitute new claims 37-86 therefor as follows:

WHAT IS CLAIMED IS:

37. (New) An optical signalling system comprising first and second signalling devices,

the first signalling device comprising a plurality of signalling elements each having a common signalling function, the signalling elements being arranged in a predetermined spatial configuration with gaps therebetween; and

a second signalling device comprising at least one signalling element for signalling with at least one of the signalling elements of said first signalling device; and

wherein said first signalling device further comprises at least one additional optical element arranged to reduce the apparent size of the gaps between adjacent elements.

38. (New) A system according to claim 37, wherein said at least one additional optical element comprises a corresponding plurality of microlenses positioned in front of the signalling elements.

39. (New) A system according to claim 37, wherein said at least one additional optical element comprises at least one beamsplitter, wherein said plurality of signalling elements are arranged in at least two groups and wherein the at least one beamsplitter and the at least two groups are arranged so that the signalling elements of the at least two groups are effectively spatially interleaved with one another.

40. (New) A system according to claim 37, wherein the at least one additional optical element comprises a second plurality of signalling elements each having the same signalling function as the signalling elements of the first plurality of signalling

FINNEGAN
HENDERSON
FARABOW
GARRETT &
DUNNER LLP
1300 I Street, NW
Washington, DC 20005
202.408.4000
Fax 202.408.4400
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elements, the second plurality of signalling elements being arranged in a predetermined spatial configuration with gaps therebetween, the second plurality of signalling elements being offset at an angle relative to the first plurality of signalling elements.

41. (New) A system according to claim 37, wherein the plurality of signalling elements are arranged in an array.

42. (New) A system according to claim 41, wherein the signalling elements are arranged in a regular array.

43. (New) A system according to claim 41, wherein the array is a two dimensional array.

44. (New) A system according to claim 41, wherein the array is a one dimensional array.

45. (New) A system according to claim 37, wherein a lens system is provided in front of the plurality of signalling elements in said first signalling device and a lens system is provided in front of the signalling element within said second signalling device.

46. (New) A system according to claim 45, wherein the lens system of said first signalling device comprises a telecentric lens.

47. (New) A system according to claim 46, wherein said plurality of signalling elements are located substantially at the back focal plane of said telecentric lens.

48. (New) A system according to claim 46, wherein said telecentric lens is a wide angled telecentric lens.

49. (New) A system according to claim 37, wherein said plurality of signalling elements comprises an array of light emitters.

50. (New) A system according to claim 37, wherein said plurality of signalling elements comprises an array of light reflectors.

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HENDERSON
FARABOW
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1300 I Street, NW
Washington, DC 20005
202.408.4000
Fax 202.408.4400
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51. (New) A system according to claim 50, wherein said first signalling device further comprises a modulator operable to modulate light reflected by or to be reflected by said array of reflectors.

52. (New) A system according to claim 37, wherein said second signalling device comprises a plurality of signalling elements.

53. (New) A system according to claim 52, wherein said plurality of said signalling elements in said second signalling device are arranged in a regular array.

54. (New) A system according to claim 53, wherein one or more of said signalling elements of said second signalling device comprises a vertical cavity surface emitting laser.

55. (New) A system according to claim 53, wherein one or more of said signalling elements of said second signalling device comprises a light detector.

56. (New) A system according to 55, wherein the or each light detector comprises a photodiode.

57. (New) A system according to claim 37, wherein said first and second signalling devices are moveable relative to each other.

58. (New) A system according to claim 37, wherein said at least one additional optical element is operable for increasing an average packing density of the plurality of signalling elements.

59. (New) A system according to claim 37, comprising a plurality of said first signalling devices arranged to signal with one or more of said second signalling devices.

60. (New) A system according to claim 37, comprising a plurality of said second signalling devices each arranged to signal with a respective one of said signalling elements of said first signalling device.

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HENDERSON
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1300 I Street, NW
Washington, DC 20005
202.408.4000
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61. (New) A system according to claim 37, wherein the signalling elements of said first signalling device are operable to modulate an optical signal to be transmitted to said second signalling device.

62. (New) A system according to claim 61, wherein said signalling elements of said first signalling device are operable to modulate at least one of the amplitude, phase, frequency and polarisation of the optical signal.

63. (New) A signalling device comprising a plurality of signalling elements arranged in a predetermined spatial configuration with gaps therebetween and at least one further optical element for reducing the apparent size of the gaps between the adjacent elements.

64. (New) A signalling device according to claim 63, wherein said at least one additional optical element comprises a corresponding plurality of microlenses positioned in front of the signalling element.

65. (New) A signalling device according to claim 63, wherein said at least one additional optical element comprises at least one beam splitter, wherein said plurality of signalling elements are arranged in at least two groups and wherein the at least one beam splitter and the at least two groups are arranged so that the signalling elements of the least two groups are effectively spatially interleaved with one another.

66. (New) A signalling device according to claim 63, wherein the at least one additional optical element comprises a second plurality of signalling elements each having the same signalling function as the signalling elements of the first plurality of signalling elements, the second plurality of signalling elements being arranged in a predetermined spatial configuration with gaps therebetween, the second plurality of signalling elements being offset at an angle relative to the first plurality of signalling elements.

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HENDERSON
FARABOW
GARRETT &
DUNNER LLP

1300 I Street, NW
Washington, DC 20005
202.408.4000
Fax 202.408.4400
www.finnegan.com

67. (New) A signalling device according to claim 63, wherein the plurality of signalling elements are arranged in an array.

68. (New) A signalling device according to claim 67, wherein the signalling elements are arranged in a regular array.

69. (New) A signalling device according to claim 67, wherein the array is a two-dimensional array.

70. (New) A signalling device according to claim 67, wherein the array is a one-dimensional array.

71. (New) A signalling device according to claim 63, further comprising a lens system provided in front of the plurality of signalling elements.

72. (New) A signalling device according to claim 71, wherein the lens system comprises a telecentric lens.

73. (New) A signalling device according to claim 72, wherein said plurality of signalling elements are located substantially at the back focal plane of said telecentric lens.

74. (New) A signalling device according to claim 72, wherein said telecentric lens is a wide-angled telecentric lens.

75. (New) A signalling device according to claim 63, wherein said plurality of signalling elements comprises an array of light emitters.

76. (New) A signalling device according to claim 63, wherein said plurality of signalling elements comprises an array of light reflectors.

77. (New) A signalling device according to claim 76, further comprising a modulator operable to modulate light reflected by or to be reflected by said array of reflectors.

FINNEGAN
HENDERSON
FARABOW
GARRETT &
DUNNER LLP

1300 I Street, NW
Washington, DC 20005
202.408.4000
Fax 202.408.4400
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78. (New) A signalling device according to claim 63, wherein said at least one additional optical element is operable for increasing an average packing density of the plurality of signalling elements.

79. (New) A signalling kit comprising one or more first signalling devices and a plurality of second signalling devices,

wherein each first signalling device comprises a signalling device according to claim 63, and

wherein each second signalling device comprises at least one signalling element for signalling with at least one of the signalling elements of said one or more first signalling device.

80. (New) A signalling method using first and second signalling devices, the first signalling device comprising a plurality of signalling elements arranged in a predetermined spatial configuration with gaps therebetween, the method comprising providing at said first signalling device at least one additional optical element for reducing the apparent size of the gaps between adjacent elements.

81. (New) An optical signalling system comprising first and second signalling devices,

the first signalling device comprising an optical signal generator operable to generate an optical signal; a modulator operable to modulate the generated optical signal with modulation data; and a reflector operable to reflect the generated optical signal towards said second signalling device;

the second signalling device comprising a receiver operable to receive optical signals transmitted from the first signalling device; a data retriever operable to retrieve the modulation data from the received signal; a modulator operable to modulate the received optical signal with modulation data for the first signalling device; and a reflector operable to reflect the received optical signal back to the first signalling device.

FINNEGAN
HENDERSON
FARABOW
GARRETT &
DUNNER LLP

1300 I Street, NW
Washington, DC 20005
202.408.4000
Fax 202.408.4400
www.finnegan.com

82. (New) An optical signalling system comprising first and second signalling devices,

the first signalling device comprising a plurality of reflectors and a light source for illuminating said plurality of reflectors in common;

the second signalling device comprising a plurality of reflectors each for receiving light from a respective light source and for reflecting the light back to the respective light source.

83. (New) A system according to claim 82, wherein said reflectors are arranged in an array.

84. (New) A system according to claim 82, wherein said first signalling device further comprises a modulator operable to modulate the light from said light source with modulation data and wherein said second signalling device further comprises a data retriever operable to retrieve the modulation data.

85. (New) A system according to claim 82, wherein said second signalling device further comprises a modulator operable to modulate the light from said first signalling device with modulation data and wherein said first signalling device further comprises a data retriever operable to retrieve the modulation data.

86. (New) An optical signalling system comprising first and second signalling devices, wherein each of the first and second signalling devices comprises a retro-reflector and at least one of the first and second signalling devices comprises an optical signal generator operable to generate and output an optical signal onto the retro-reflector of said at least one of said first and second signalling devices.

FINNEGAN
HENDERSON
FARABOW
GARRETT &
DUNNER LLP

1300 I Street, NW
Washington, DC 20005
202.408.4000
Fax 202.408.4400
www.finnegan.com

REMARKS

Claims 37-86 are currently pending. These claims have been amended to conform them to U.S. practice and to eliminate multiple claims dependency. No new matter has been introduced by these amendments.

The examiner is respectfully requested to consider the above preliminary amendment prior to examination of the application. If there are fees due in connection with the filing of this Preliminary Amendment, please charge the fees to Deposit Account No. 06-0916.

Respectfully submitted,

FINNEGAN, HENDERSON, FARABOW,
GARRETT & DUNNER, L.L.P.

Dated: January 8, 2002

By: ______________________
Ernest F. Chapman
Reg. No. 25,961

EFC/FPD/sci

FINNEGAN
HENDERSON
FARABOW
GARRETT &
DUNNER LLP

1300 I Street, NW
Washington, DC 20005
202.408.4000
Fax 202.408.4400
www.finnegan.com

SIGNALLING SYSTEM

The present invention relates to a signalling system. One aspect of the invention relates to an optical free space signalling method and apparatus.

The applicant has proposed in their earlier International application WO98/35328 a point to multipoint data transmission system which uses a retroreflector to receive collimated laser beams from a plurality of user terminals, to modulate the received laser beams and to reflect them back to the respective user terminals. This point to multipoint data transmission system employs pixelated reflector/modulator arrays and a telecentric optical lens systems. The system operates by assigning each user of the system a unique pixel in the array. Each pixel in the array is matched to a unique angular position in the field of view of the telecentric optical lens system.

The inventors have found, however, that the system described in this International application suffers from the problem that there are locations within the field of view of the optical lens system where communication between the transmitter and receiver cannot occur reliably. The inventors have identified that this is because of the pixelated nature of the reflector/modulator array used in the system. In particular, since there are gaps between the pixels in the array, there are areas in the field of view of the

optical lens system which do not correspond to the pixels of the reflector/modulator array. This problem can be minimised by minimising the gaps between the pixels. However, in practice this is difficult to achieve since the pixels must be electrically isolated from each other and space must be provided to allow connections to be made to the individual pixels.

The present invention aims to alleviate the problems described above by providing at least one additional optical element to increase the apparent packing density of the communication pixels.

According to one aspect, the present invention provides a communication system which employs a plurality of arrays of communication elements which are optically combined to increase their effective packing density (i.e. to increase the effective area covered by the communication elements compared to the gaps between the elements). Preferably the plurality of arrays are arranged so that the packing density is increased to 100% to provide maximum coverage.

According to another aspect, the present invention provides an optical communication system having an array of optical communication elements and a micro lens array positioned in front of the array of elements to increase the apparent packing density of the elements.

According to another aspect, the present invention

provides an optical communication system having two or more telecentric optical systems which are offset in angle from each other and which include a respective array of communication elements.

Exemplary embodiments of the present invention will now be described with reference to the accompanying drawings in which:

Figure 1 is a schematic diagram of a video broadcast system for supplying video signals for a plurality of television channels, to a plurality of remote users;

Figure 2 is a schematic block diagram of a local distribution node and a user terminal which forms part of the video broadcast system shown in Figure 1;

Figure 3 is a schematic diagram of a retroreflector array and lens system employed in the local distribution node shown in Figure 2;

Figure 4 is a schematic diagram of an optically combined pixelated retroreflector array which forms part of the system shown in Figure 3;

Figure 5 is a schematic diagram of a data distribution system;

Figure 6 is a schematic diagram of a local distribution node and a user terminal which forms part of the data

distribution system shown in Figure 5;

Figure 7 is a schematic diagram of an emitter and detector array and lens system employed in the local distribution node shown in Figure 6;

Figure 8 is a schematic diagram of a data distribution system for supplying data to a plurality of users;

Figure 9 is a schematic diagram of an array of emitters and detectors which forms part of one of the user terminals in the system shown in Figure 8;

Figure 10 is a schematic diagram of an alternative form of local distribution node and user terminal which can be used in the data distribution system shown in Figure 1;

Figure 11 is a schematic diagram of an alternative form of local distribution node and user terminal which can be employed in the data distribution system shown in Figure 1;

Figure 12 is schematic diagram of an alternative form of local distribution node and user terminal which can be employed in the data distribution system shown in Figure 1;

Figure 13 is a schematic diagram of an alternative form of local distribution node and user terminal which can be employed in the data distribution system shown in Figure

1;

Figure 14 is a schematic diagram of an alternative form of an optically combined pixelated communications cell array which may be used in any of the above embodiments;

Figure 15 is a schematic diagram of an alternative form of an optically combined pixelated communication cell array which may be used in any of the embodiments described above;

Figure 16 is a schematic block diagram of a retroflector array and lens system which may be employed in the local distribution node shown in Figure 2 and which includes a micro lens array for increasing the apparent packing density of the communication cells; and

Figure 17 is a schematic block diagram of two telecentric optical systems and modulator arrays which are offset at an angle from each other.

Figure 1 schematically illustrates a video broadcast system for supplying video signals, for a plurality of television channels, to a plurality of remote users. As shown in Figure 1, the system comprises a central distribution system 1 which transmits optical video signals to a plurality of local distribution nodes 3 via a bundle of optical fibres 5. The local distribution nodes 3 are arranged to receive the optical video signals transmitted from the central distribution system 1 and to

transmit relevant parts of the video signals to respective user terminals 7 (which are spatially fixed relative to the local distribution node 3) as optical signals through free space, i.e. not as optical signals along an optical fibre path.

In this embodiment, the video data for all the available television channels is transmitted from the central distribution system 1 to each of the local distribution nodes 3, each user terminal 7 informs the appropriate local distribution node 3 which channel or channels it wishes to receive (by transmitting an appropriate request) and, in response, the local distribution node 3 transmits the appropriate video data, to the respective user terminals 7. Each local distribution node 3 does not, however, broadcast the video data to the respective user terminals 7. Instead, each local distribution node 3 is arranged (i) to receive an optical beam transmitted from each of the user terminals 7 which are in its locality, (ii) to modulate the received beams with the appropriate video data for the desired channel or channels, and (iii) to reflect the modulated beams back to the respective user terminals 7. In addition to being able to receive optical signals from the central distribution system 1 and from the user terminal 7, each of the local distribution nodes 3 can also transmit optical data, such as status reports, back to the central distribution system 1 via the respective optical fibre bundle 5, so that the central distribution system 1 can monitor the status of the distribution network.

Figure 2 schematically illustrates in more detail the main components of one of the local distribution nodes 3 and one of the user terminals 7 of the system shown in Figure 1. As shown in Figure 2, the local distribution node 3 comprises a communications control unit 11 which (i) receives the optical signals transmitted along the optical fibre bundle 5 from the central distribution system 1; (ii) regenerates the video data from the received optical signals; (iii) receives messages 12 transmitted from the user terminals 7 and takes appropriate action in response thereto; and (iv) converts the appropriate video data into data 14 for modulating the respective light beams 15 received from the user terminals 7. In converting the video data into modulation data 14, the communications control unit 11 will encode the video data with error correction coding and coding to reduce the effects of inter-symbol-interference and other kinds of well known sources of interference such as from the sun and other light sources.

The local distribution node 3 also comprises a retro-reflector and modem unit 13, which is arranged to receive the optical beams 15 from the user terminals 7 which are within its field of view, to modulate the respective light beams with the appropriate modulation data 14 and to reflect the modulated beams back to the respective user terminals 7. In the event that an optical beam 15 received from one of the user terminals 7 carries a message 12, then the retro-reflector and modem unit 13

retrieves the message 12 and sends it to the communications control unit 11 where it is processed and the appropriate action is taken. In this embodiment, the retro-reflector and modem unit 13 has a horizontal field of view which is greater than +/- 50° and a vertical field of view of approximately +/- 5°.

Figure 2 also shows the main components of one of the user terminals 7. As shown, the user terminal 7 comprises a laser diode 17 for outputting a laser beam 19 of coherent light. In this embodiment, the user terminals 7 are designed so that they can communicate with the local distribution node 3 within a range of 150 metres with a link availability of 99.9 per cent. To achieve this, the laser diode 17 is a 50 mW laser diode which outputs a laser beam having a wavelength of 850 nm. This output laser beam 19 is passed through a collimator 21 which reduces the angle of divergence of the laser beam 19. The resulting laser beam 23 is passed through a beam splitter 25 to an optical beam expander 27, which increases the diameter of the laser beam for transmittal to the retro-reflector and modem unit 13 located in the local distribution node 3. The optical beam expander 27 is used because a large diameter laser beam has a smaller divergence than a small diameter laser beam. Additionally, increasing the diameter of the laser beam also has the advantage of spreading the power of the laser beam over a larger area. Therefore, it is possible to use a higher powered laser diode 17 whilst still meeting eye-safety requirements.

Using the optical beam expander 27 has the further advantage that it provides a fairly large collecting aperture for the reflected laser beam and it concentrates the reflected laser beam into a smaller diameter beam. The smaller diameter reflected beam is then split from the path of the originally transmitted laser beam by the beam splitter 25 and focused onto a photo-diode 29 by a lens 31. Since the operating wavelength of the laser diode 17 is 850nm, a silicon avalanche photo-diode (APD) can be used, which is generally more sensitive than other commercially available photo detectors, because of the low noise multiplication which can be achieved with these devices. The electrical signals output by the photo-diode 29, which will vary in dependence upon the modulation data 14, are then amplified by the amplifier 33 and filtered by the filter 35. The filtered signals are then supplied to a clock recovery and data retrieval unit 37 which regenerates the clock and the video data using standard data processing techniques. The retrieved video data 38 is then passed to the user unit 39, which, in this embodiment, comprises a television receiver in which the video data is displayed to the user on a CRT (not shown).

In this embodiment, the user unit 39 can receive an input from the user, for example indicating the selection of a desired television channel, via a remote control unit (not shown). In response, the user unit 39 generates an appropriate message 12 for transmittal to the local distribution node 3. This message 12 is output to a

laser control unit 41 which controls the laser diode 17 so as to cause the laser beam 19 output from the laser diode 17 to be modulated with the message 12. As those skilled in art will appreciate, in order that the data being transmitted in opposite directions do not interfere with each other, different modulation techniques should be employed. For example, if the amplitude of the laser beam 15 is modulated by the local distribution node 3, then the laser control unit 41 should modulate, for example, the phase of the transmitted laser beam. Alternatively, the laser control unit 41 could apply a small signal modulation to the laser beam 19 to create a low-bandwidth control channel between the user terminal 7 and the local distribution node 3. This is possible provided the detector in the local distribution node 3 can detect the small variation in the amplitude of the received laser beam. Furthermore, such a small signal amplitude modulation of the laser beam would not affect a binary "on" and "off" type modulation which could be employed by the retro-reflector and modem unit 13.

The structure and function of the components in the user terminal 7 are well known to those skilled in the art and a more detailed description of them shall, therefore, be omitted.

Figure 3 schematically illustrates the retro-reflector and modem unit 13 which forms part of the local distribution node 3 shown in Figure 2. As shown, in this embodiment, the retro-reflector and modem unit 13

comprises a wide angle telecentric lens system 51, two arrays of modulators and detectors 53a and 53b and a beamsplitter 54 for dividing beams from the telecentric lens system 51 between the modulator/detector arrays 53a and 53b. In this embodiment, the telecentric lens system 51 comprises lens elements 61 and 55 and a stop member 57, having a central aperture 59. The size of the aperture 59 is a design choice and depends upon the particular requirements of the installation. The structure and function of a telecentric lens system is described in the applicants earlier International application WO 98/35328, the content of which is incorporated herein by reference.

As is illustrated in Figure 3 by the two sets of rays 67 and 69, laser beams from different sources are focused onto different parts of the arrays of modulators/detectors 53a, 53b. Therefore, by using an array of separate modulators and detectors, the laser beams 15 from all the user terminals 7 can be separately detected and modulated by a respective modulator and detector pair.

In this embodiment, each of the modulator/detector arrays 53a and 53b comprises 100 columns and 10 rows of modulator/detector cells. As shown in Figure 3, these arrays are located at the back focal plane 62a and 62b of the lens system 51. The cells of these arrays are spatially staggered from each other so that the cells in array 53b are optically located in the spaces between the

cells of array 53a. This is schematically illustrated in Figure 4, which shows the optically combined modulator/detector arrays 53a and 53b. As shown, the cells c^2_{ij} of the array 53b are positioned so that the are optically located between the cells c^1_{ij} of the array 53a. As a result, the packing density of the cells is significantly increased compared to the packing density of the individual arrays 53a and 53b. As shown, each modulator/detector cell c_{ij} comprises a modulator m_{ij} and a detector d_{ij} located adjacent the corresponding modulator. In this embodiment, the size 71 of the cells c_{ij} is between 50 and 200 μm, with the spacing (centre to centre) 72 between the cells being slightly smaller than the cell size 71.

As shown in Figure 4, the telecentric lens 51 is designed so that the spot size of a focused laser beam from one of the user terminals 7 corresponds with the size 71 of one of the modulator/detector cells c_{ij}, as illustrated by the shaded circle 73 shown in Figure 4, which covers the modulator/detector cell $c^1_{10\,1}$. The way in which the laser beams from the user terminals 7 are aligned with the retro-reflector and the way in which the system initially assigns the modulator/detector cells to the respective user terminals is described in WO 98/35328 and will not be described again here.

In this embodiment, Quantum Confined Stark Effect (QCSE, sometimes also referred to as Self Electro-optic Effect Devices or SEEDs) modulators, developed by the American

Telephone and Telegraph Company (AT&T), are used for the modulators m_{ij}. The structure and function of these QCSE modulators is described in WO 98/35328 and will not be given here. In this embodiment, each of the detectors d_{ij} comprises a photo-diode which is connected to an associated amplifier, filter and clock recovery and data retrieval unit similar to those employed in the user terminal 7 shown in Figure 2, which operate to detect any modulation of the corresponding laser beam and to regenerate any messages 12 which are transmitted from the corresponding user terminal 7. All the recovered messages 12 are then transmitted back to the communications control unit 11 where they are processed and appropriate actions are taken.

Figure 5 schematically shows a data distribution system which employs a point to multipoint signalling system. The data distribution system is similar to the video data distribution system shown in Figure 1, except that data is passed in only one direction, from the central distribution system 1 to the user terminals 7. Such a data distribution system can be employed to distribute information relating to, for example, the prices of shares which are bought and sold on a stock market. In such an application, the individual user terminals 7 would comprise a display unit for displaying the new prices of the stocks to the traders so that they can be kept up-to-date with changes in the share prices. Alternatively, such a one-way data distribution system could be used in railway stations, airports and the like

for informing passengers of arrivals and departures etc.

The local distribution node 3 used in this embodiment is similar to the local distribution node of the system shown in Figure 1. The only difference is that the cells in the arrays do not include detectors d_{ij}, for receiving communications transmitted from the user terminals 7. Similarly, the user terminals 7 are similar to those of the first embodiment except that there is no need for the optical beam expander in front of the beam splitter nor a laser control circuit for modulating the laser diode for transmitting messages to the local distribution nodes. The remaining components of this embodiment are the same and will not, therefore, be described again.

In the above embodiments, a retro-reflecting communication system was described. As those skilled in the art will appreciate, the above technique for increasing the packing density is also applicable to systems which use an array of light emitters rather than an array of retro-reflectors. Figure 6 schematically illustrates in more detail the main components of one of the local distribution nodes 3 and one of the user terminals 7 of such an embodiment. As shown in Figure 6, the local distribution node 3 comprises a communications control unit 11 which (i) receives the optical signals transmitted along the optical fibre 5 from the central distribution system 1; (ii) regenerates the video data from the received optical signals; (iii) receives messages 12 transmitted from the user terminals 7 and

takes appropriate action in response thereto; and (iv) converts the appropriate video data into data 14 for transmission from the emitter elements of the emitter/detector array and lens system 80. The emitter/detector array and lens system 80, which is arranged (i) to receive the optical beams 15 from the user terminals 7 which are within its field of view and to transmit the received messages 12 to the communications control unit 11 where they are processed and the appropriate action taken; and (ii) to transmit the respective video data 14, via optical beams 15, to the respective user terminals 7.

As shown in Figure 6, the user terminal 7 is identical to that of Figure 2.

Figure 7 schematically illustrates the emitter and the detector array and lens system 80 which forms part of the local distribution node 3 shown in Figure 6. As shown, in this embodiment, the emitter and detector array and lens system 80 comprises a lens system 89, two arrays of emitters/detectors 90a, 90b and a beam splitter 54 located between the arrays 90 and the lens system 89. As shown, the lens system 89 comprises a wide angled lens 55 and a convex lens 87 which operate to provide a wide field of view for the emitter and detector array and lens system 80. In this embodiment, the lens system 89 is not telecentric. Each of the emitter/detector arrays 90a and 90b comprise a regular array of communication cells similar to the cells formed in the modulator/detector

arrays of the first embodiment, except with the modulators replaced by light emitters. In this embodiment, the emitters are formed from vertical cavity surface emitting lasers (hereinafter referred to as VCSELs). The VCSEL array is preferred because the array can be manufactured from a single semiconductor wafer, without having to cut the wafer. This allows a higher number of the emitter elements per unit area than would be the case with an array made from traditional laser diodes.

These VCSEL arrays, manufactured and sold by CSEM SA (Badenerstrasse 569, 8048 Zurich, Switzerland), operate in a power range of between 1 and 30 mW and output a laser beam having a wavelength the same as conventional laser diodes. Again, the cells of the arrays 90a and 90b are spatially arranged so that, through the operation of the beam splitter 54, the cells of the arrays are interleaved with each other like the cells shown in Figure 4.

In this embodiment, the VCSEL emitters e_{ij} in the emitter arrays 90a, 90b are selectively addressable and the data 14 from the communications control unit includes respective data for each VCSEL emitter e_{ij}. The data for each VCSEL emitter may be the same or it may be different, depending on the application. As shown in Figure 7, the light output by each emitter e_{ij} in the arrays 90a, 90b is a diverging beam, the divergence being primarily caused by diffraction at the emitting aperture

of the laser. The lens system 89 collects the diverging beam from each emitter and forms it into a collected beam. As those skilled in the art will appreciate, and as illustrated by the light rays 95 and 97, the angle at which the collected beam leaves the exit pupil of the lens depends on the spatial position of the emitter in the arrays 90a or 90b. Therefore, each emitter in each array maps to a particular angle in space and can therefore communicate with a respective user terminal 7.

In the above embodiments, simplex and duplex data distribution systems have been described in which a number of fixed user terminals can communicate with a local distribution node. An embodiment will now be described with reference to Figures 8 and 9 which describe a data distribution system similar to the system described with reference to Figures 5 to 7 except that some of the user terminals 7 (such as user terminal u^1_m) can receive data from more than one local distribution node 3. In this way, some of the user terminals can receive twice the amount of data from the local distribution nodes or, if the local distribution nodes transmit the same data, then some of the user terminals 7 will have an uninterrupted communication link even if the line of sight linked with one of the local distribution nodes become blocked.

In this embodiment, the local distribution nodes 3 are substantially the same as the local distribution node shown in Figure 7, except that the lens system is

telecentric, like the lens system shown in Figure 3, and the arrays are just emitter rays. In this embodiment, telecentric lenses are used since this allows the collection efficiency (of light from the emitter arrays 90) of the lens to be constant across the emitter arrays. Therefore, provided that all the emitter elements are the same, the intensity of the light output from the local distribution node will be the same for each emitter. In contrast, with a non-telecentric lens, the intensity of the light output from the local distribution node will be greater for light emitted by emitters in the centre of the array than for those at the edge. The use of a telecentric lens also avoids the various cosine fall-off factors which are well known in conventional lenses.

In order to allow the user terminals to be able to simultaneously receive different communications from the different local distribution nodes 3, the user terminals include arrays of detector cells similar to the arrays of emitter cells located in the local distribution nodes 3. Figure 9 schematically illustrates the lens system and detector array 100 which forms part of a user terminal 7 and which replaces the lens 31 and photo diode 29 of Figure 6. As shown, the lens system 101 comprises a wide angle lens 103 and a convex lens 105, and operates to focus light received from different local distribution nodes 3 (represented by light rays 106 and 107) onto a beamsplitter 109 which divides the beams between the two detector arrays 108a and 108b. In this embodiment, the detector cells in the two detector arrays 108a and 108b

are spatially arranged so that they are interleaved with each other, like the cells shown in Figure 4. As those skilled in the art will appreciate, by providing two of these detector arrays optically combined by the beam splitter 109, the packing density of the detector arrays can be increased over the packing density obtainable through a single array.

As those skilled in the art will appreciate and as mentioned above, one of the advantages of this embodiment is that if one of the laser beams (106 or 107) from one of the local distribution nodes 3 is blocked, then the user terminal 7 will still receive the data from the other beam. Another advantage of this embodiment is that since both sides of the free space communications link use wide angled lenses, their fields of view are relatively large. Therefore, successful communications can still be carried out even if the user terminal 7 moves relative to the local distribution node 3, provided both remain within the other's field of view.

Another advantage of this embodiment is that if the user terminals 7 do move relative to the local distribution nodes 3, then they can determine either when they are about to move out of the field of view of one of the local distribution nodes 3 or when one of the local distribution nodes 3 is about to move out of their field of view. This is possible because as the user terminals 7 move, the laser beams from the local distribution nodes 3 move over the respective detector array 108a, 108b and

the user terminals 7 can detect this by sampling the signals from the detector cells in their arrays. In such an embodiment, if the user terminal 7 determines that the laser beam from one of the local distribution nodes 3 is about to move off the side of the detector array 108a, 108b and if the user terminal 7 is not receiving data from another local distribution node 3, then the user terminal 7 may be configured so as to warn the user that connection to the central distribution system 1 is about to be lost. As those skilled in the art will appreciate, in such an embodiment where the user terminals 7 move relative to the local distribution nodes 3 (or vice versa), either side of the communication link can track the movement of the other side within its field of view by tracking the focussed laser beam from the other side as it moves over its emitter/detector arrays. This information can then be used to control the emitter and detector cell which is used in the communications link.

A simplex communications system was described above in which emitter arrays were provided in each of the local distribution nodes and detector arrays were provided in each of the user terminals. As those skilled in the art will appreciate, and as shown in Figure 10, the communication system shown in Figure 8 can be made into a duplex communication system by providing emitter and detector arrays in both the local distribution nodes 3 and the user terminals 7. Preferably, in such an embodiment, each side of the communications link would use a wide angled telecentric lens such as the one shown

in Figure 3, for the reasons mentioned above. Alternatively, as illustrated in Figure 11, emitter and detector arrays may be provided in the local distribution nodes 3 and retroreflector and modulator arrays may be provided in each of the user terminals 7. Alternatively still, as illustrated in Figure 12, a retroreflector and modem unit may be provided in each of the local distribution nodes 3 and emitter and detector arrays may be provided in each of the user terminals 7.

Alternatively still, retroreflector and modem units may be provided in both the local distribution nodes 3 and the user terminal 7. Such an embodiment is illustrated in Figure 13. As those skilled in the art will appreciate, in such an embodiment, either the local distribution node or the user terminal must also include a laser diode for illuminating the light reflectors of one of the retroreflectors. In the embodiment shown in Figure 13, this laser diode is provided in the local distribution node 3. As shown, light from the laser diode 111 is expanded and collimated by the lens 112 and used to illuminate the modulator array 113 via a polarising beamsplitter 114. Each element of the modulator array reflects or absorbs a part of the incident light in accordance with the electric bias applied to that element (which depends on the input modulation data 14). The reflected light then passes through the beamsplitter and a $\lambda/4$ wave plate 119 (for changing the polarisation of the reflected light from linear to circular) and lens 115 towards the user

terminal 7. The beam received at the user terminal is focussed by a lens 116 onto a retro-reflector array (including both modulators and detectors) 117 where the received light is both detected (to recover the modulation data 14) and modulated with data 12 and reflected back towards the local distribution node 3. As a result of this reflection, the "handedness" of the polarised light is inverted and therefore, when the reflected light passes again through the $\lambda/4$ wave plate 119, the linear polarisation of the received light is rotated by 90° relative to the transmitted light. Therefore, the reflected light is reflected by the polarising beamsplitter 114 towards the photodiode array 118, where the modulation data 12 is recovered. As those skilled in the art will appreciate, the techniques described above which are used to increase the effective packing density of the retro-reflectors may also be employed in this embodiment at one or at both ends of the communications link.

In the above embodiment, two arrays of modulators were combined using a beam splitter 54. As a result, the apparent packing density of the arrays of modulator/detector cells is increased. However, with 2D arrays, a packing density of 100% cannot be achieved with only two arrays of such modulator/detector cells. However, if four arrays of modulator/detector cells are used, each having a packing density of at least 25% (i.e. in which the gap between the pixels is equal to or greater than the pixel size), then by employing three

beamsplitters, these four arrays may be optically combined to achieve a 100% packing density. This is schematically illustrated in Figure 14.

Further, in some applications, users of the communication system will be distributed in a substantially horizontal plane. Therefore, in this case, a linear array of modulators/detectors is sufficient and a 100% packing density can be achieved through just two linear arrays, as illustrated in Figure 15.

In the above embodiments, two arrays of optical communication elements (such a light emitters, light reflectors and light detectors) were optically combined using beamsplitters in order to increase the packing density of the optical elements. The packing density of the optical elements can be effectively increased using other techniques. For example, an array of microlenses may be placed in front of the array of optical elements. In this case the microlens array would be arranged so that the centres of the microlens have the same grid spacing as that of the elements in the optical element array, so that each microlens acts as an optical system for an individual optical element. This is illustrated in Figure 16 which shows the way in which such an array of microlenses 135 may be placed in front of an array of optical communication elements (in this case an array of QCSE modulators 53). As illustrated in Figure 16, each of the microlenses 137 is located adjacent a modulator pixel 53-1, which, in this embodiment, are spaced apart along

the array 53 by regular intervals 53-2. As shown, each of the microlenses 137 acts to form a magnified image of the associated modulator pixel, so that, when viewed from the exit pupil of the telecentric optical system 51, the array appears to have a 100% packing density.

As those skilled in the art will appreciate, by using such a microlens array, the numerical aperture of the beam at the modulator pixel will be larger than without the lens by a factor equal to the linear magnification afforded by the microlens. With 30μm modulator elements and with a spacing between the elements of 5μm, the linear magnification required to achieve a 100% packing density is 1.167, and hence the numerical aperture at the pixel is increased by this factor. However, this is a relatively small increase in numerical aperture and in most cases is well within acceptable limits for the modulator pixel.

Another way of increasing the packing density of a single array of optical communication elements is to use two or more separate optical systems and arrays of communication elements. Such a system is schematically illustrated in Figure 17. As shown, the system includes two telecentric optical systems 120a and 120b and two arrays 125a and 125b of optical communication elements. This embodiment makes use of the fact that a beam 127 incident upon the transmitter or receiver is typically significantly larger than the telecentric stop of the telecentric lens. Therefore, the beam can be received by more than one

telecentric system. Therefore, by pointing the two telecentric lens systems in slightly different directions, as shown in Figure 17, the mapping between direction within the field of view and position on the arrays 125a and 125b, for the two arrays will be different. Therefore, by setting the appropriate offset angle between the two telecentric lens systems, the communications elements in the two arrays 125a and 125b can be arranged to intermesh in a similar manner to the embodiments which employ beamsplitters. As those skilled in the art will appreciate, this technique can achieve a 100% packing density without the additional optical loss associated with beamsplitters, but at the cost of additional telecentric optical systems.

In the retro-reflecting embodiments described above, an array of QCSE modulators were used in the retro-reflecting end of the communication link. These QCSE modulators either absorb or reflect incident light. As those skilled in the art will appreciate, other types of reflectors and modulators can be used. For example, a plane mirror may be used as the reflector and a transmissive modulator (such as a liquid crystal) may be provided between the lens and the mirror. Alternatively still, beamsplitters may be used to temporarily separate the path of the incoming beam from the path of the reflected beam and, in this case, the modulator may be provided in the path of the reflected beam so that only the reflected light is modulated. However, such an embodiment is not preferred since it requires additional

optical components to split the forward and return paths and then to re-combine the paths after modulation has been effected.

In the embodiments which employ a telecentric lens, the array of emitters or detectors or modulators are located substantially at the back focal plane of the telecentric lens. As those skilled in the art will appreciate, the telecentric lens can be adapted to have a back focal plane which is curved or partially curved. In this case, the array of emitters or detectors or modulators should also be curved or partially curved to match the back focal plane of the telecentric lens.

In the above embodiments, a point to multipoint signalling system has been described. As those skilled in the art will appreciate, many of the communications techniques described above will apply to point to point signalling systems, to multipoint to point signalling systems and multipoint to multipoint signalling systems.

In the embodiments described above which employ arrays of VCSEL emitters, the light generated by each of the emitters is modulated with the data to be transmitted to the other end of the communication link. The easiest way to modulate the light from the VCSEL emitters is to switch the emitters on and off to thereby amplitude modulate the light emitted from them. However, as those skilled in the art will appreciate, other modulation techniques, such as frequency or phase modulation may be

used. Further, as those skilled in the art will appreciate, other types of light emitters such as laser diodes and light emitting diodes may be used. An array of emitters could also be formed by a bundle of optical fibres, closely packed into a regular array with a laser diode coupled to the other end of each fibre. However, the use of such a bundle of optical fibres or the use of 2D arrays of laser diodes results in a greater beam divergence caused by diffraction at the emitting aperture which is of the order of ±20°. This requires a low f/number collimating lens to be used if the light is to efficiently collected and collimated. This increases the cost and complexity of the lens system.

CLAIMS

1. An optical signalling system comprising first and second signalling devices,

the first signalling device comprising a plurality of signalling elements each having a common signalling function, the elements being arranged in a predetermined spatial configuration with gaps therebetween; and

a second signalling device comprising at least one signalling element for signalling with at least one of the signalling elements of said first signalling device; and

wherein said first signalling device further comprises at least one additional optical element arranged to reduce the apparent size of the gaps between adjacent elements.

2. A system according to claim 1, wherein said at least one additional optical element comprises a corresponding plurality of microlenses positioned in front of the signalling elements.

3. A system according to claim 1, wherein said at least one additional optical element comprises at least one beamsplitter, wherein said plurality of signalling elements are arranged in at least two groups and wherein the at least one beamsplitter and the at least two groups are arranged so that the signalling elements of the at

least two groups are effectively spatially interleaved with one another.

4. A system according to claim 1, wherein the at least one additional optical element comprises a second plurality of signalling elements each having the same signalling function as the signalling elements of the first plurality of signalling elements, the second plurality of signalling elements being arranged in a predetermined spatial configuration with gaps therebetween, the second plurality of signalling elements being offset at an angle relative to the first plurality of signalling elements.

5. An apparatus according to any preceding claim, wherein the or each plurality of signalling elements are arranged in an array.

6. An apparatus according to claim 5, wherein the signalling elements are arranged in a regular array.

7. A system according to claim 5, wherein the or each array is a two dimensional array.

8. A system according to claim 5, wherein the or each array is a one dimensional array.

9. A system according to any preceding claim, wherein

a lens system is provided in front of the plurality of signalling elements in said first signalling device and a lens system is provided in front of the signalling element within said second signalling device.

10. A system according to claim 9, wherein the lens system of said first signalling device comprises a telecentric lens.

11. A system according to claim 10, wherein said plurality of signalling elements are located substantially at the back focal plane of said telecentric lens.

12. A system according to claim 10 or 11, wherein said telecentric lens is a wide angled telecentric lens.

13. A system according to any preceding claim, wherein said plurality of signalling elements comprises an array of light emitters.

14. A system according to any of claims 1 to 12, wherein said array of signalling elements comprises an array of light reflectors.

15. A system according to claim 14, wherein said first signalling device further comprises means for modulating light reflected by or to be reflected by said array of

reflectors.

16. A system according to any preceding claim, wherein said second signalling device comprises a plurality of signalling elements.

17. A system according to claim 16, wherein said plurality of said signalling elements in said second signalling device are arranged in a regular array.

18. A system according to claim 17, wherein one or more of said signalling elements of said second signalling device comprises a vertical cavity surface emitting laser.

19. A system according to claim 17 or 18, wherein one or more of said signalling elements of said second signalling device comprises a light detector.

20. A system according to 19, wherein the or each light detector comprises a photodiode.

21. A system according to any preceding claim, wherein said first and second signalling devices are moveable relative to each other.

22. A system according to any preceding claim, wherein said at least one further optical element is operable for

increasing the average packing density of the plurality of signalling elements.

23. A system according to any preceding claim, comprising a plurality of said first signalling devices arranged to signal with one or more of said second signalling devices.

24. A system according to any preceding claim, comprising a plurality of said second signalling devices each arranged to signal with a respective one of said signalling elements of said first signalling device.

25. A system according to any preceding claim, wherein the signalling elements of said first signalling device are operable to modulate an optical signal to be transmitted to said second signalling device.

26. A system according to claim 25, wherein said signalling elements of said first signalling device are operable to modulate at least one of the amplitude, phase, frequency or polarisation of the optical signal.

27. A signalling device comprising a plurality of signalling elements arranged in a predetermined spatial configuration with gaps therebetween and at least one further optical element for reducing the apparent size of the gaps between the adjacent elements.

28. A signalling device comprising the technical first signalling device features of any preceding claim.

29. A signalling kit comprising one or more first signalling devices and a plurality of second signalling devices,

wherein each first signalling device comprises a signalling device according to either claim 28 or 29, and

wherein each second signalling device comprises at least one signalling element for signalling with at least one of the signalling elements of said one or more first signalling device.

30. A signalling method using first and second signalling devices, the first signalling device comprising a plurality of signalling elements arranged in a predetermined spatial configuration with gaps therebetween, the method being characterised by the step of providing at said first signalling device at least one additional optical element for reducing the apparent size of the gaps between adjacent elements.

31. An optical signalling system comprising first and second signalling devices,

the first signalling device comprising means for generating an optical signal; means for modulating the generated optical signal with modulation data; and means for reflecting the generated optical signal towards said

second signalling device;

the second signalling device comprising means for receiving optical signals transmitted from the first signalling device; means for retrieving the modulation data from the received signal; means for modulating the received optical signal with modulation data for the first signalling device; and means for reflecting the received optical signal back to the first signalling device.

32. An optical signalling system comprising first and second signalling devices,

the first signalling device comprising a plurality of reflectors and a light source for illuminating said plurality of reflectors in common;

the second signalling device comprising a plurality of reflectors each for receiving light from a respective light source and for reflecting the light back to the respective light source.

33. A system according to claim 32, wherein said reflectors are arranged in an array.

34. A system according to claim 32 or 33, wherein said first signalling device further comprises means for modulating the light from said source with modulation data and wherein said second signalling device further comprises means for retrieving the modulation data.

35. A system according to any of claims 32 to 34, wherein said second signalling device further comprises means for modulating the light from said first signalling device with modulation data and wherein said first signalling device further comprises means for retrieving the modulation data.

36. An optical signalling system comprising first and second signalling devices, wherein each of the first and second signalling devices comprises a retro-reflector and at least one of the first and second signalling devices comprises means for generating and outputting an optical signal onto the retro-reflector of said at least one of said first and second signalling devices.

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
18 January 2001 (18.01.2001)

PCT

(10) International Publication Number
WO 01/05069 A2

(51) International Patent Classification[7]: H04B 10/00

(21) International Application Number: PCT/GB00/02668

(22) International Filing Date: 10 July 2000 (10.07.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
9916080.6 8 July 1999 (08.07.1999) GB
9916422.0 13 July 1999 (13.07.1999) GB

(71) Applicant *(for all designated States except US)*: **SCIENTIFIC GENERICS LIMITED** [GB/GB]; Harston Mill, Harston, Cambridgeshire CB2 5NH (GB).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **GREEN, Alan, Edward** [GB/GB]; Scientific Generics Limited, Harston Mill, Harston, Cambridgeshire CB2 5NH (GB). **MORRISON, Euan** [GB/GB]; Scientific Generics Limited, Harston Mill, Harston, Cambridgeshire CB2 5NH (GB). **REYNOLDS, Michael** [GB/GB]; Scientific Generics Limited, Harston Mill, Harston, Cambridgeshire CB2 5NH (GB).

(74) Agents: **BERESFORD, Keith, Denis, Lewis** et al.; Beresford & Co., 2-5 Warwick Court, High Holborn, London WC1R 5DH (GB).

(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

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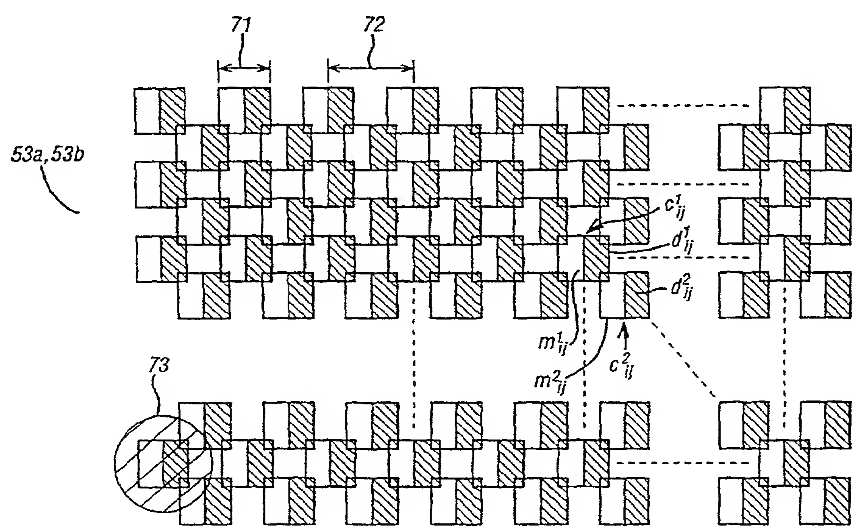
(54) Title: SIGNALLING SYSTEM



(57) Abstract: A signalling system is provided which employs one or more arrays of communication elements together with an additional optical element for increasing the apparent packing density of the elements in the arrays. In one embodiment, this is achieved by using a microlens array matched with the array of communication elements. In another embodiment two arrays are provided which are optically combined with a beamsplitter. In a third embodiment, two optical systems are provided which are offset in angle from each other so that there is a different mapping between position in the array and position within the field of view.

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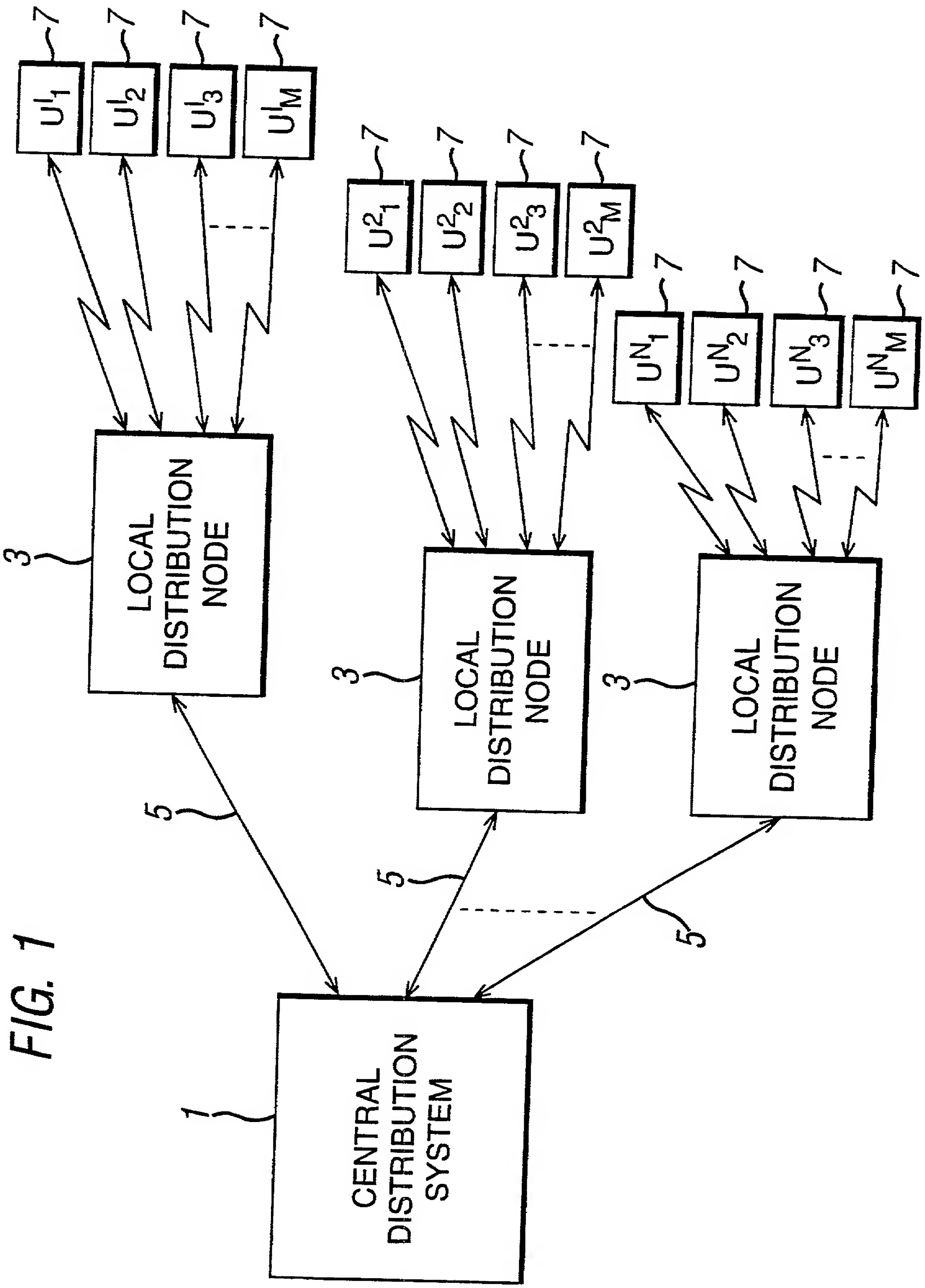
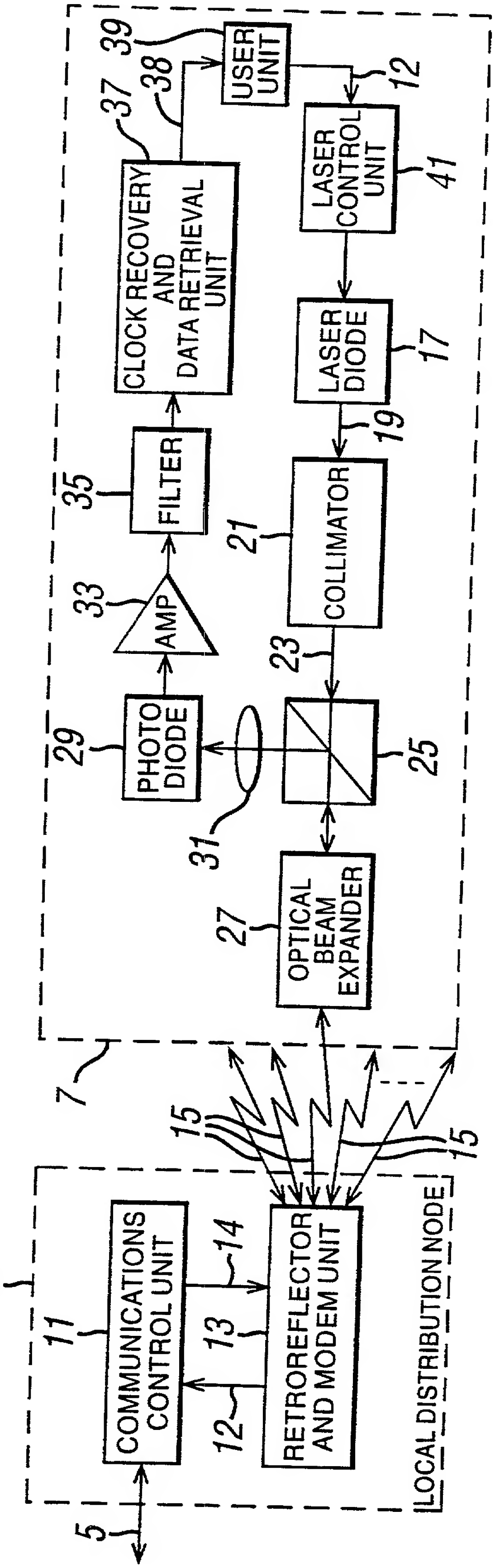


CENTRAL DISTRIBUTION SYSTEM
LOCAL DISTRIBUTION NODE
LOCAL DISTRIBUTION NODE
LOCAL DISTRIBUTION NODE
U^1_1
U^1_2
U^1_3
U^1_M
U^2_1
U^2_2
U^2_3
U^2_M
U^N_1
U^N_2
U^N_3
U^N_M
1
3
5
7

FIG. 1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RETROREFLECTOR AND MODEM UNIT
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FIG. 2

FIG. 3

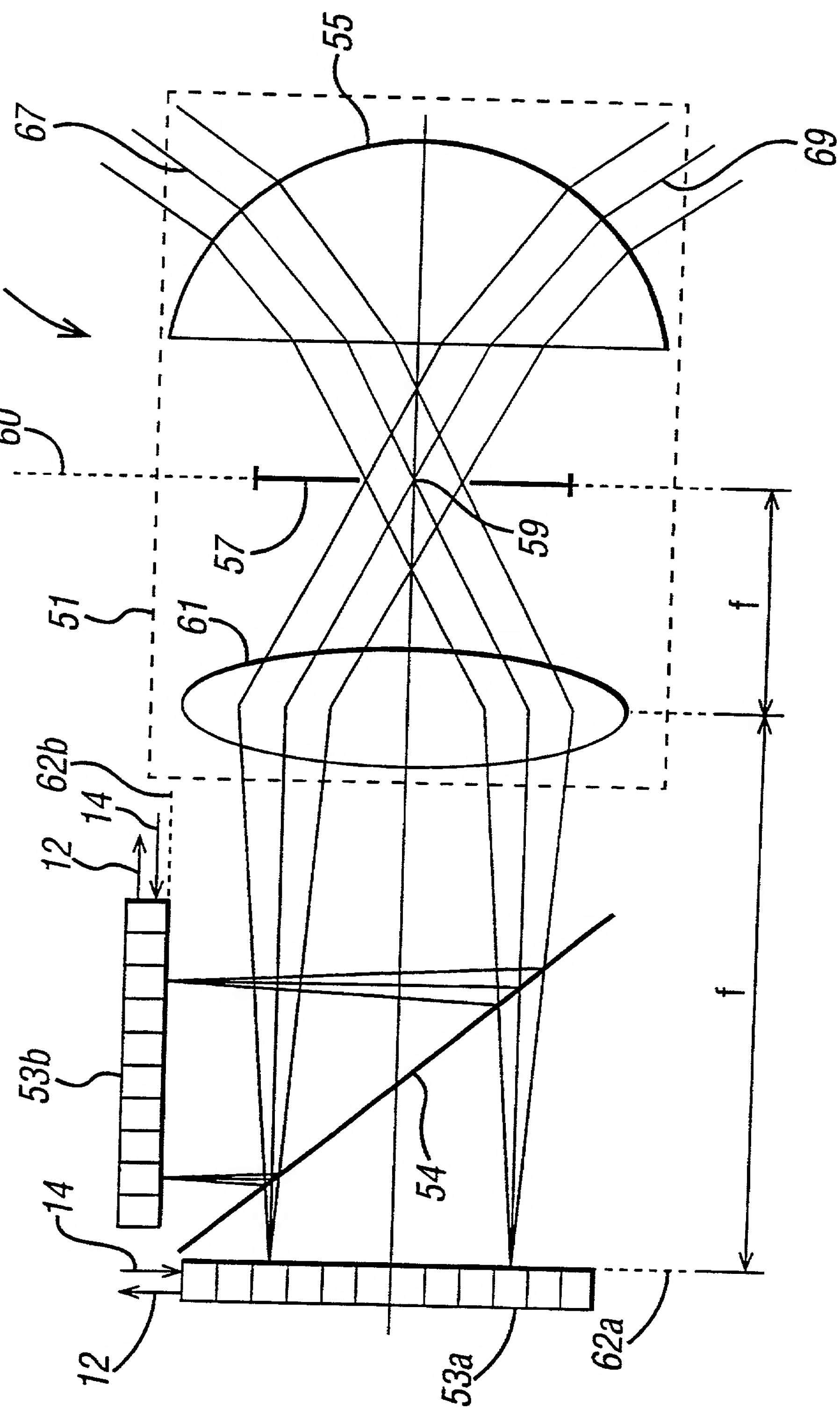
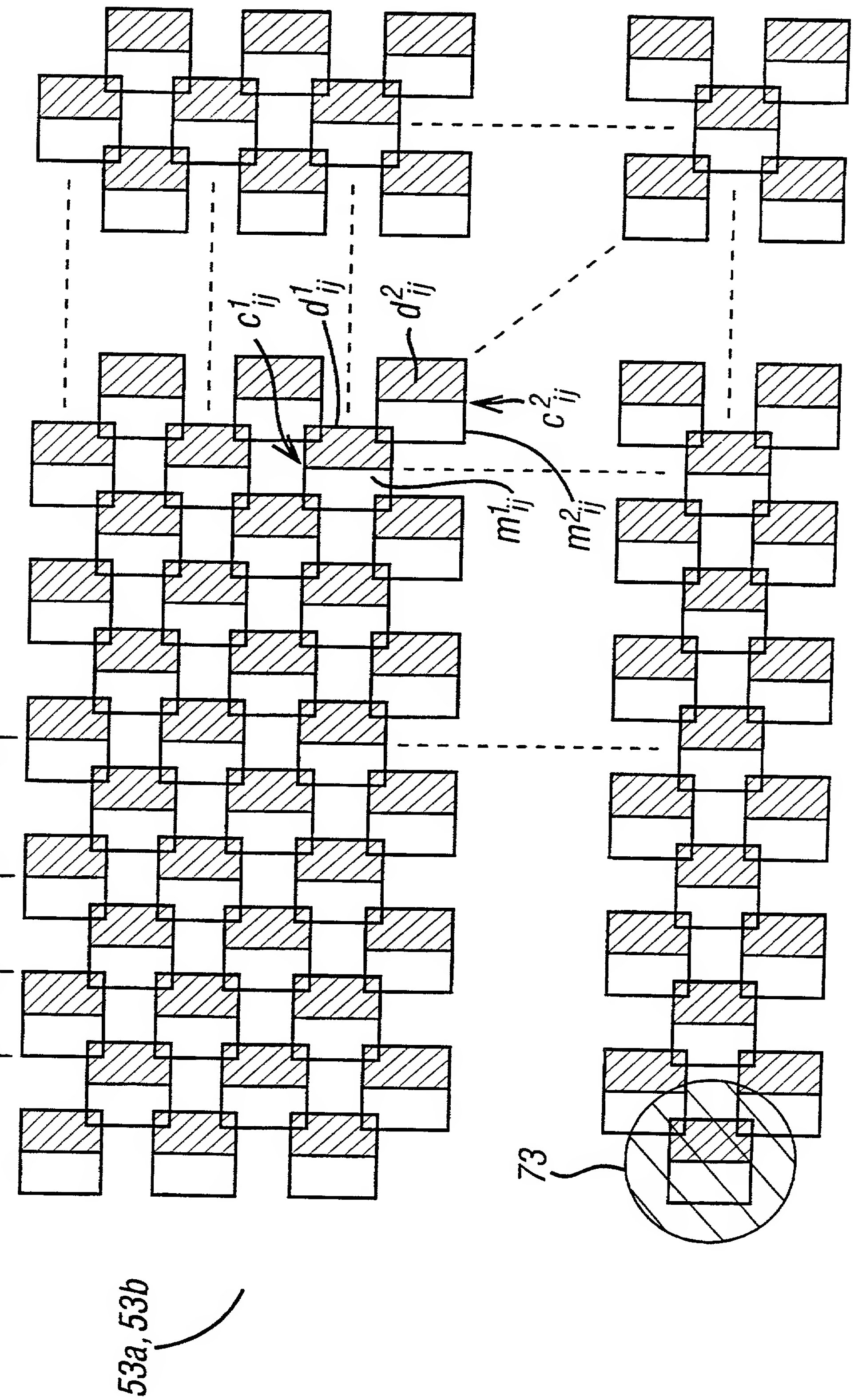


FIG. 4



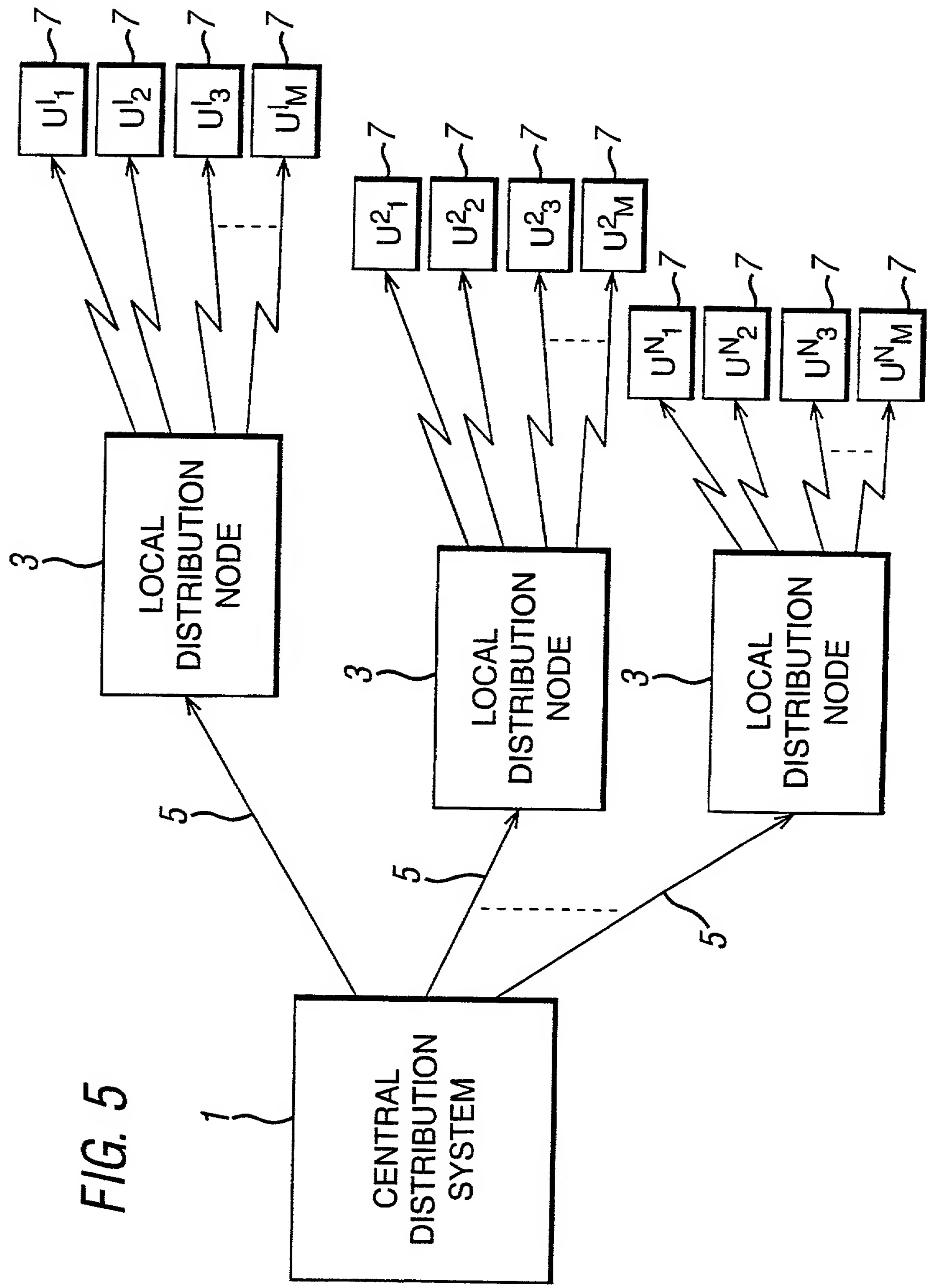

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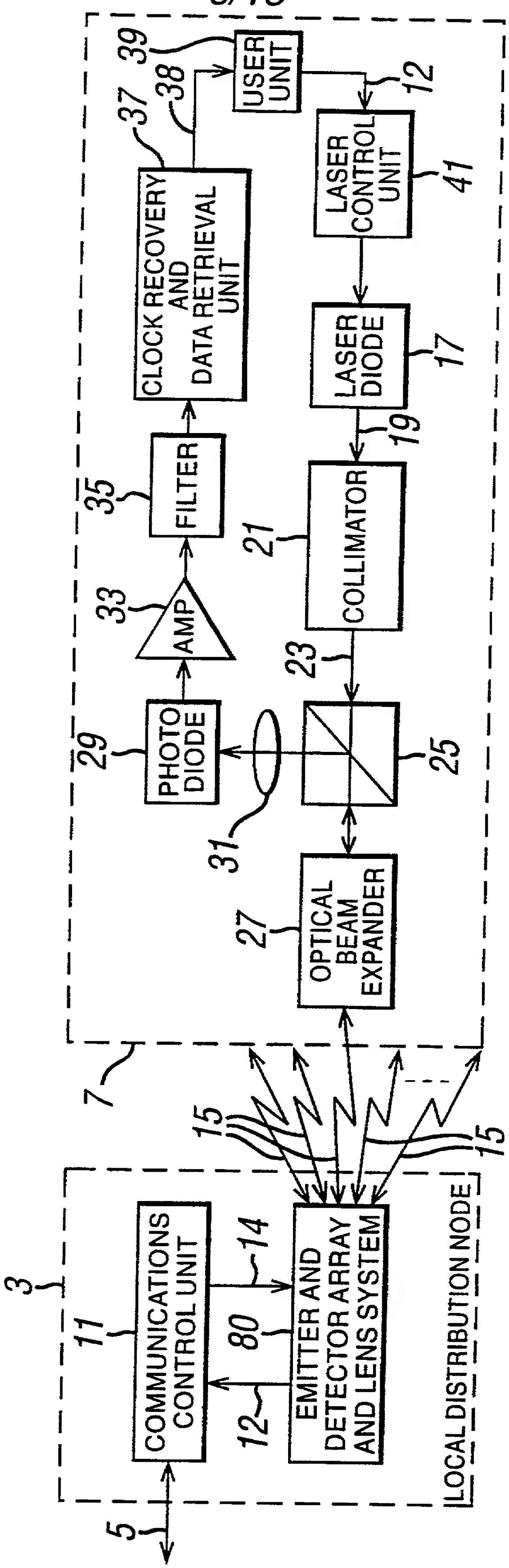
FIG. 5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COMMUNICATIONS CONTROL UNIT
EMITTER AND DETECTOR ARRAY AND LENS SYSTEM
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FIG. 6

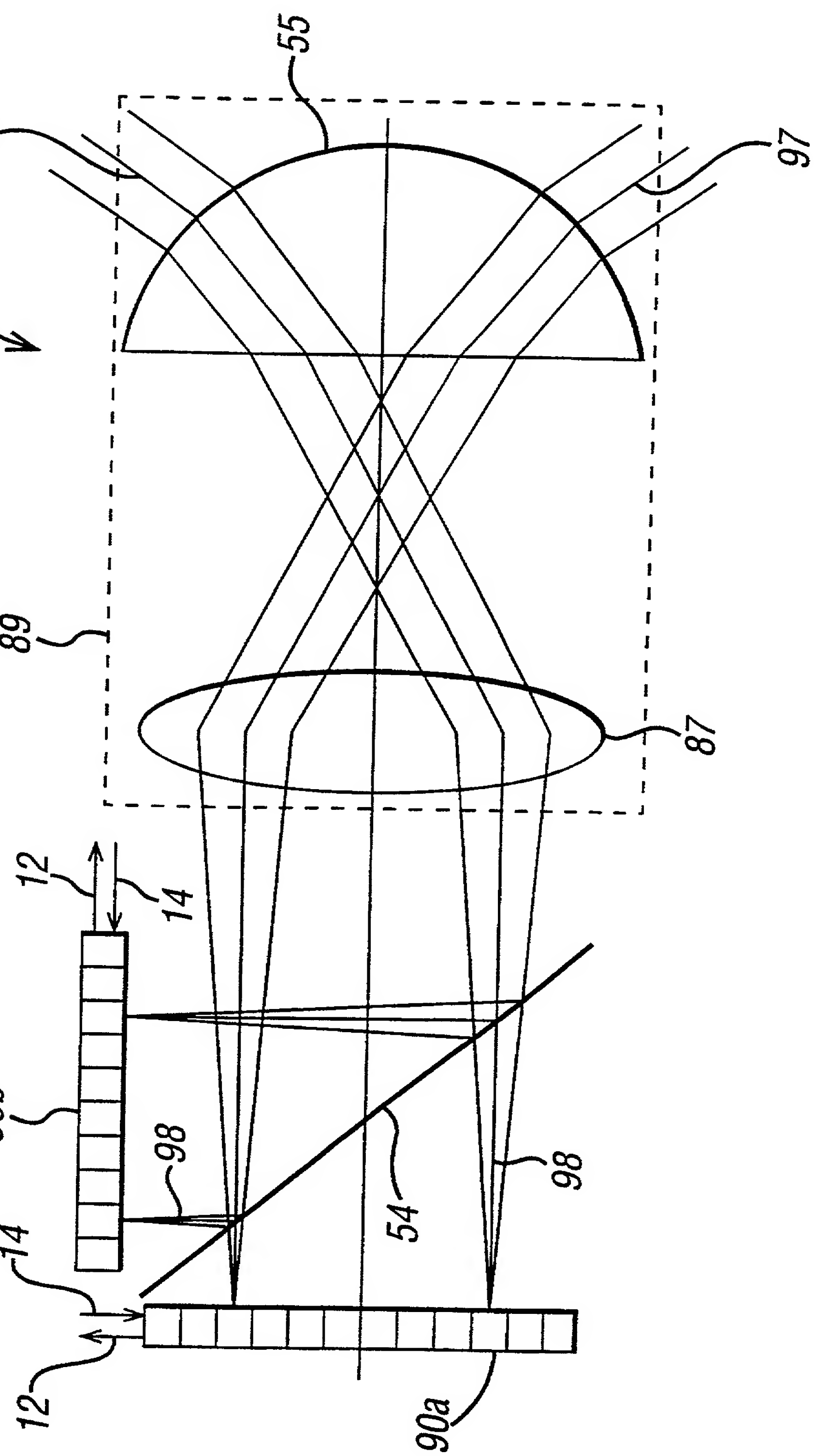

FIG. 7

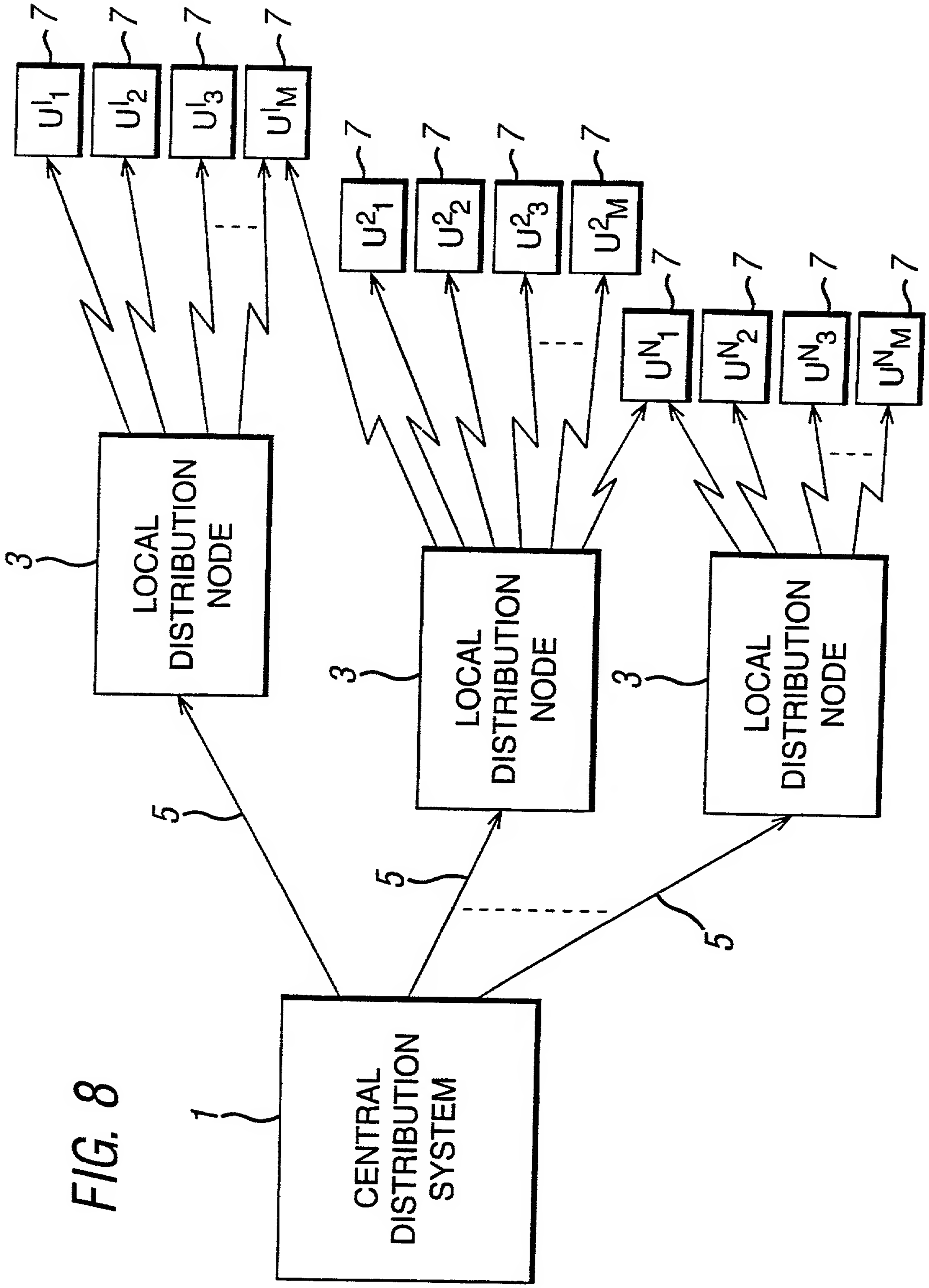
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FIG. 8

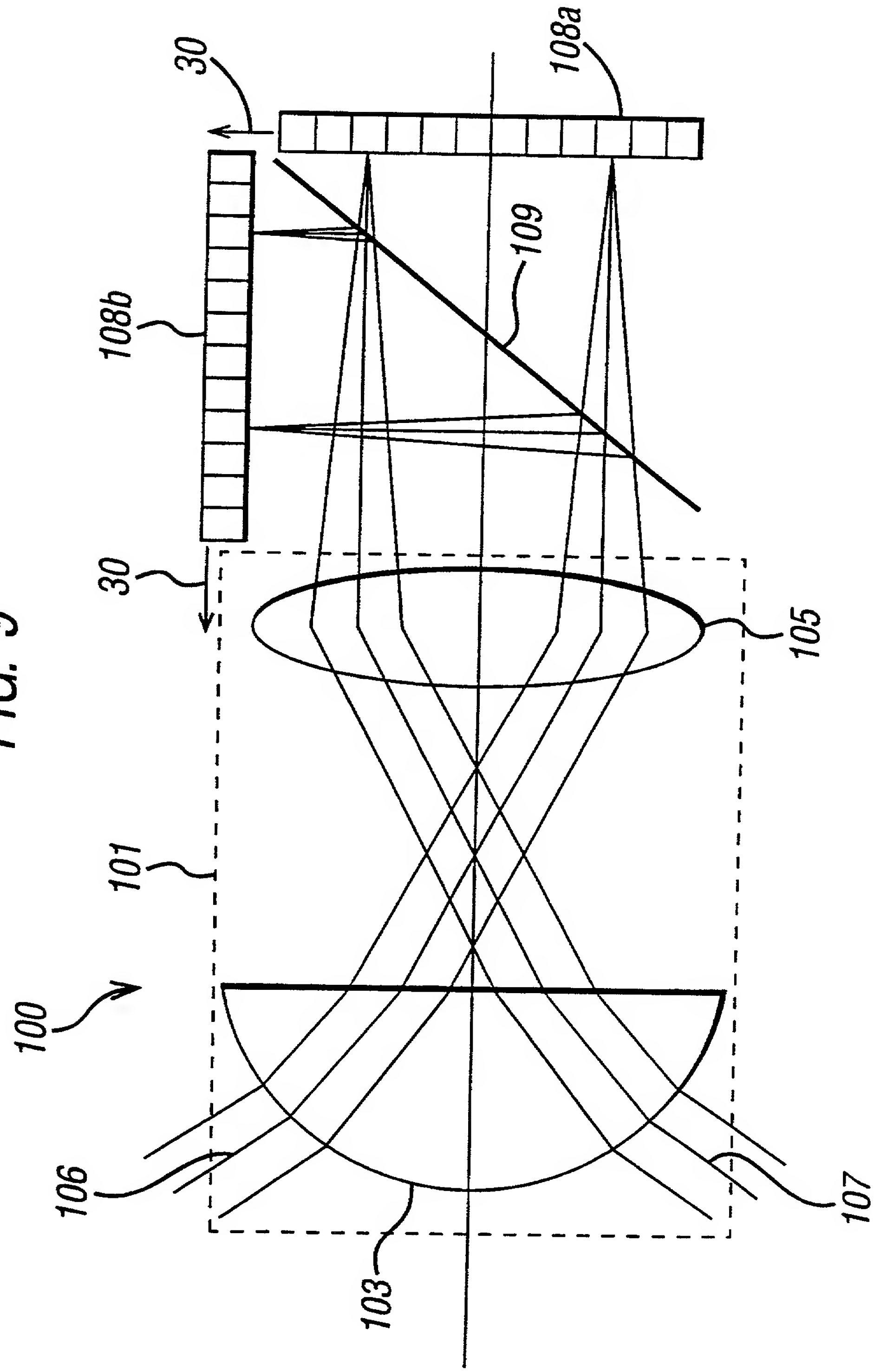
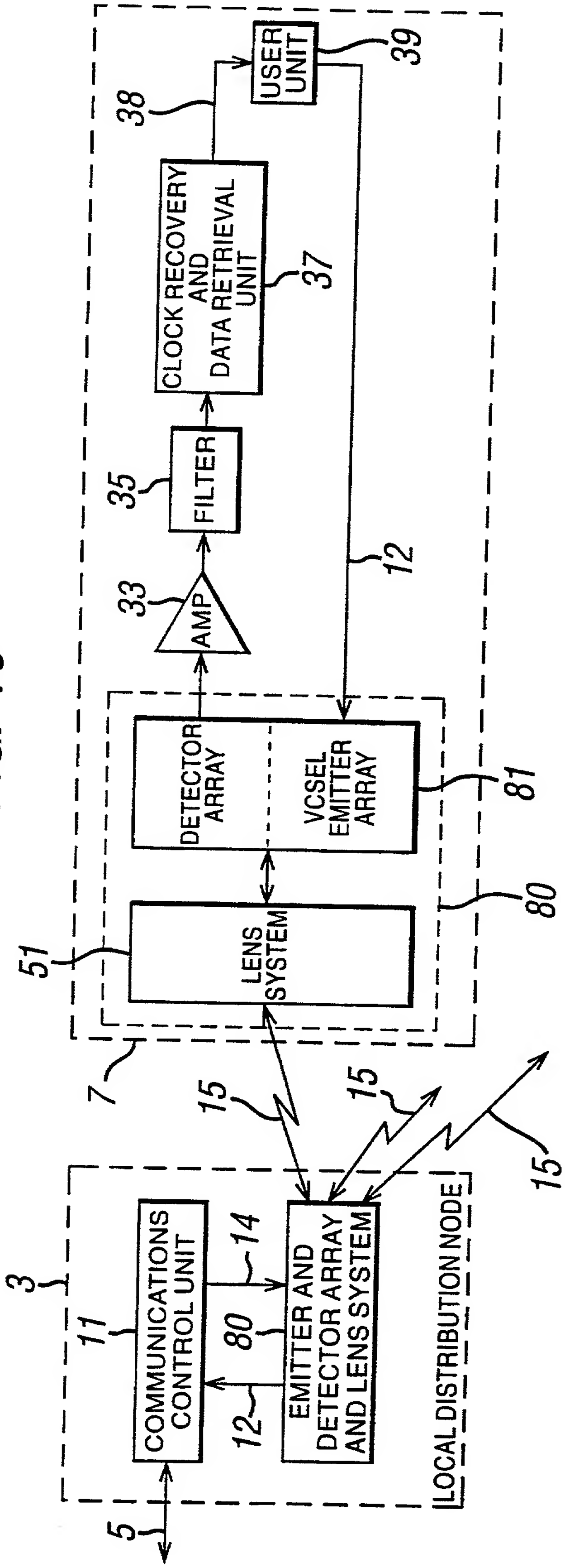


FIG. 9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VCSEL EMITTER ARRAY
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LENS SYSTEM
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EMITTER AND DETECTOR ARRAY AND LENS SYSTEM
LOCAL DISTRIBUTION NODE
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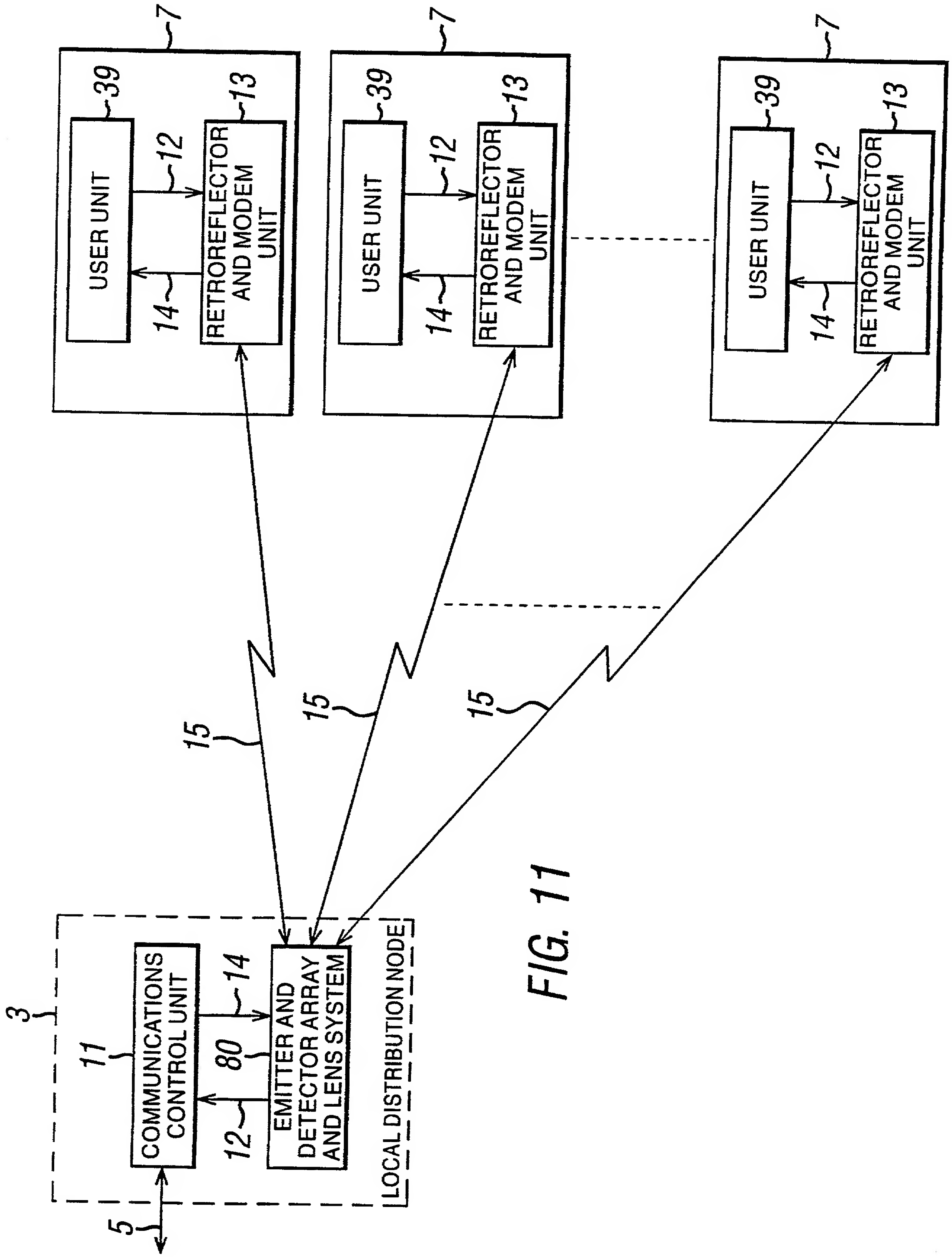
FIG. 10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EMITTER AND DETECTOR ARRAY AND LENS SYSTEM
LOCAL DISTRIBUTION NODE
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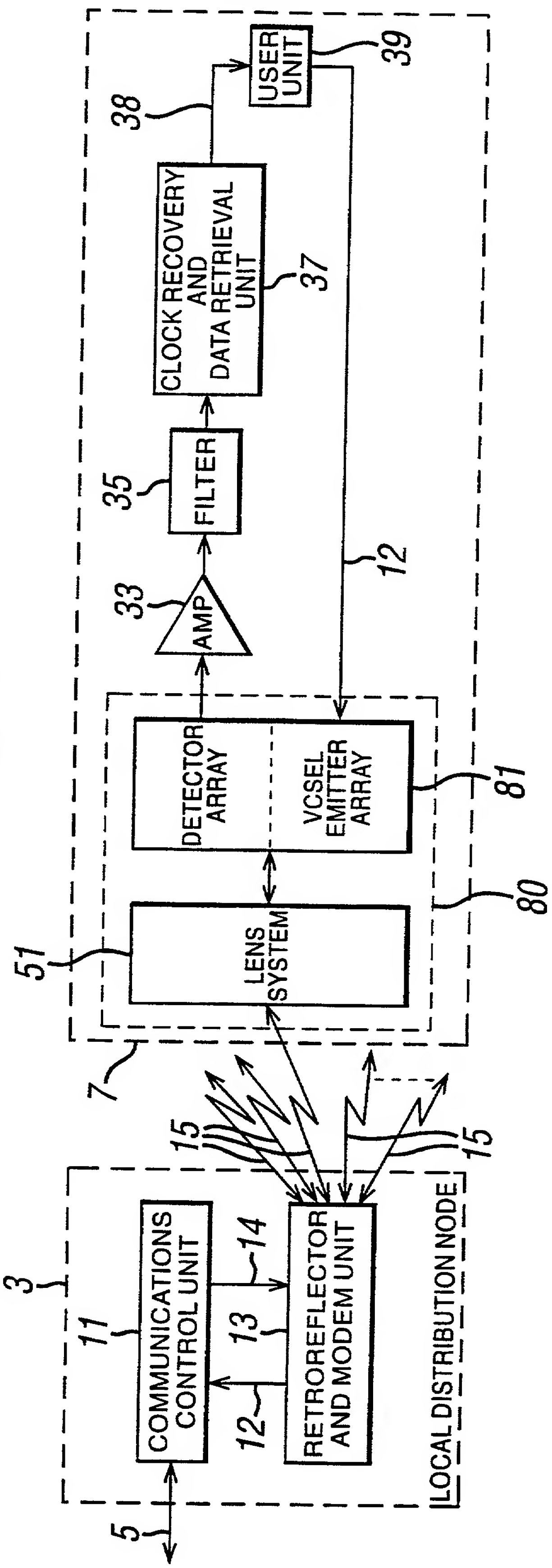
FIG. 11

FIG. 12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LENS SYSTEM
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COMMUNICATIONS CONTROL UNIT
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RETROREFLECTOR AND MODEM UNIT
LOCAL DISTRIBUTION NODE
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FIG. 13

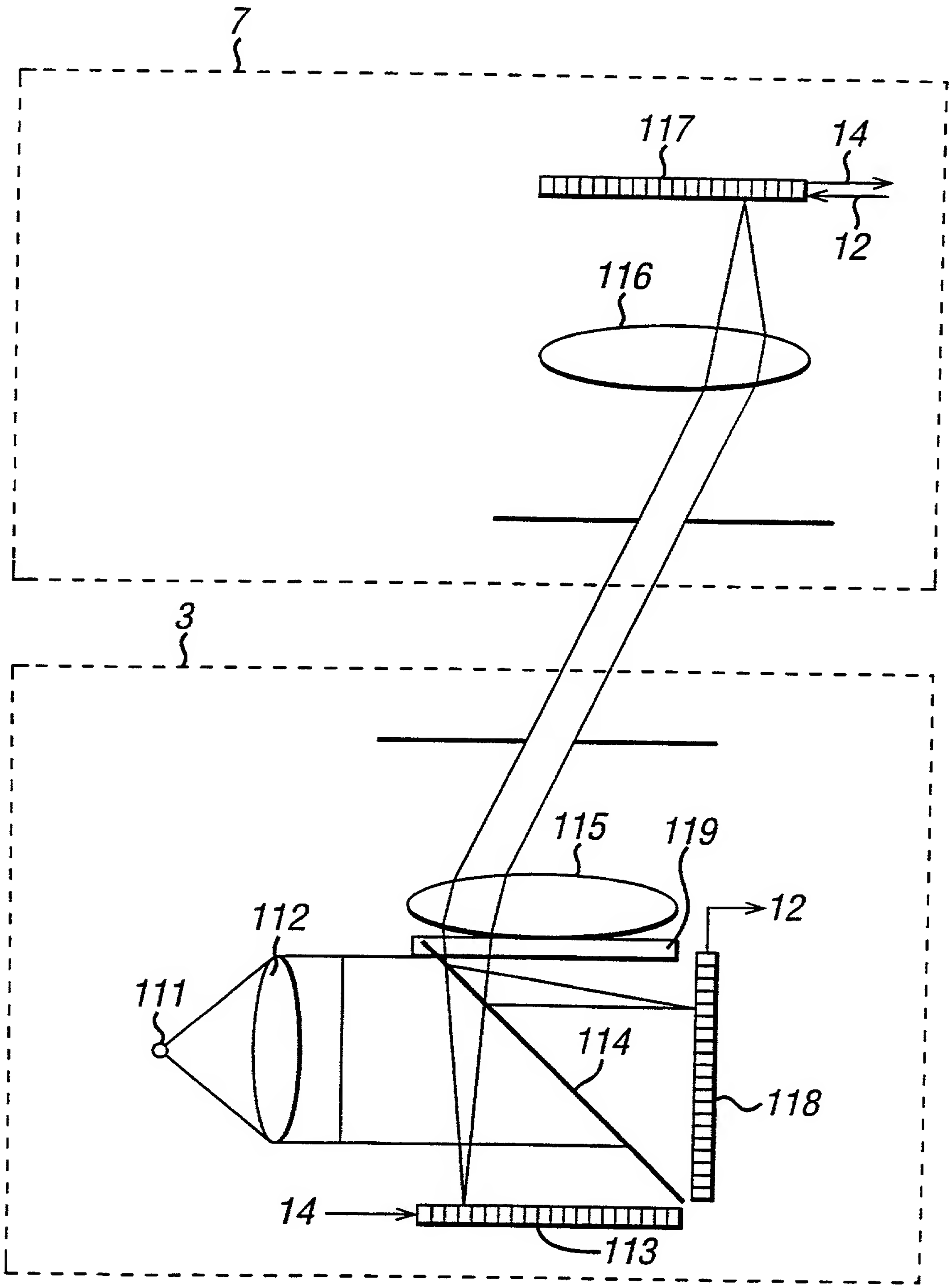


FIG. 14

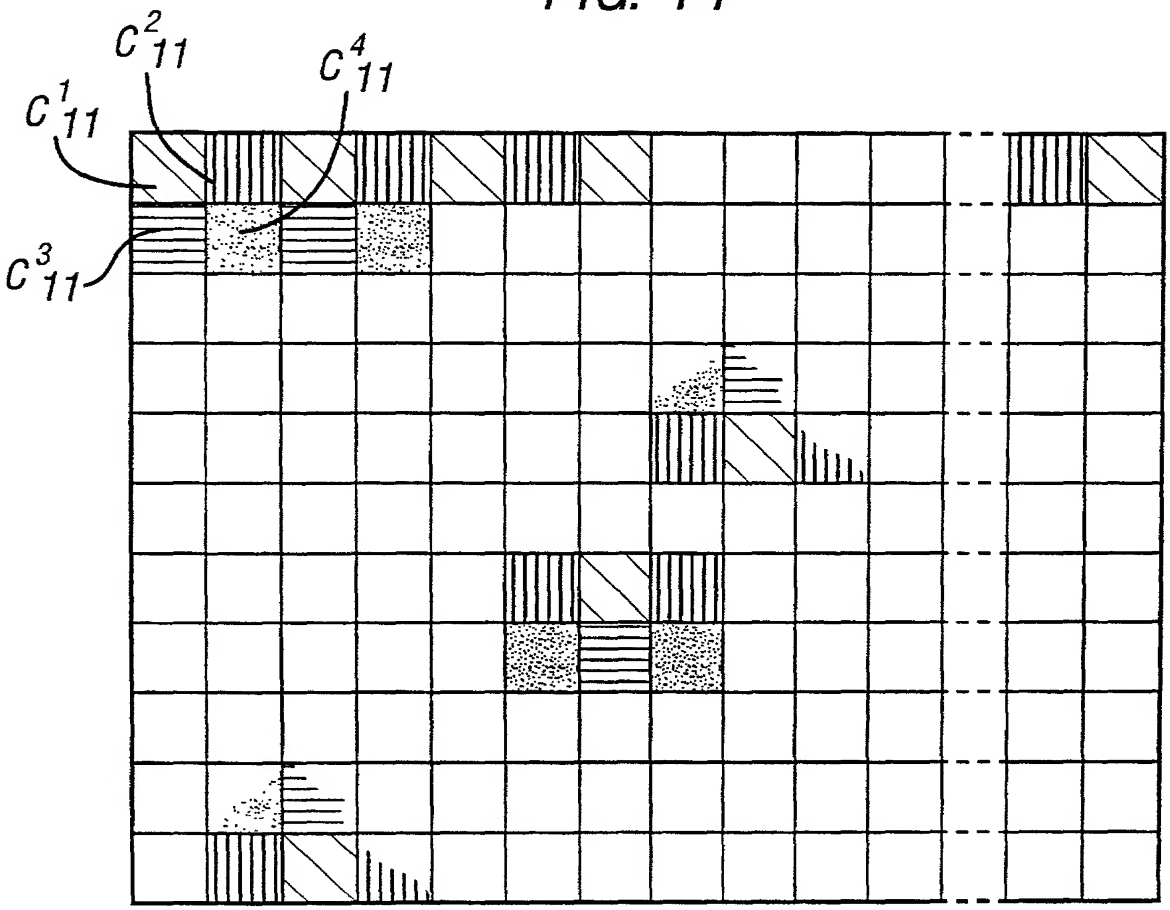
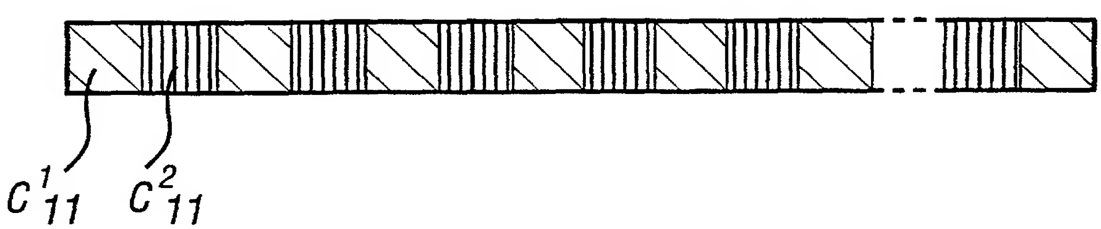


FIG. 15



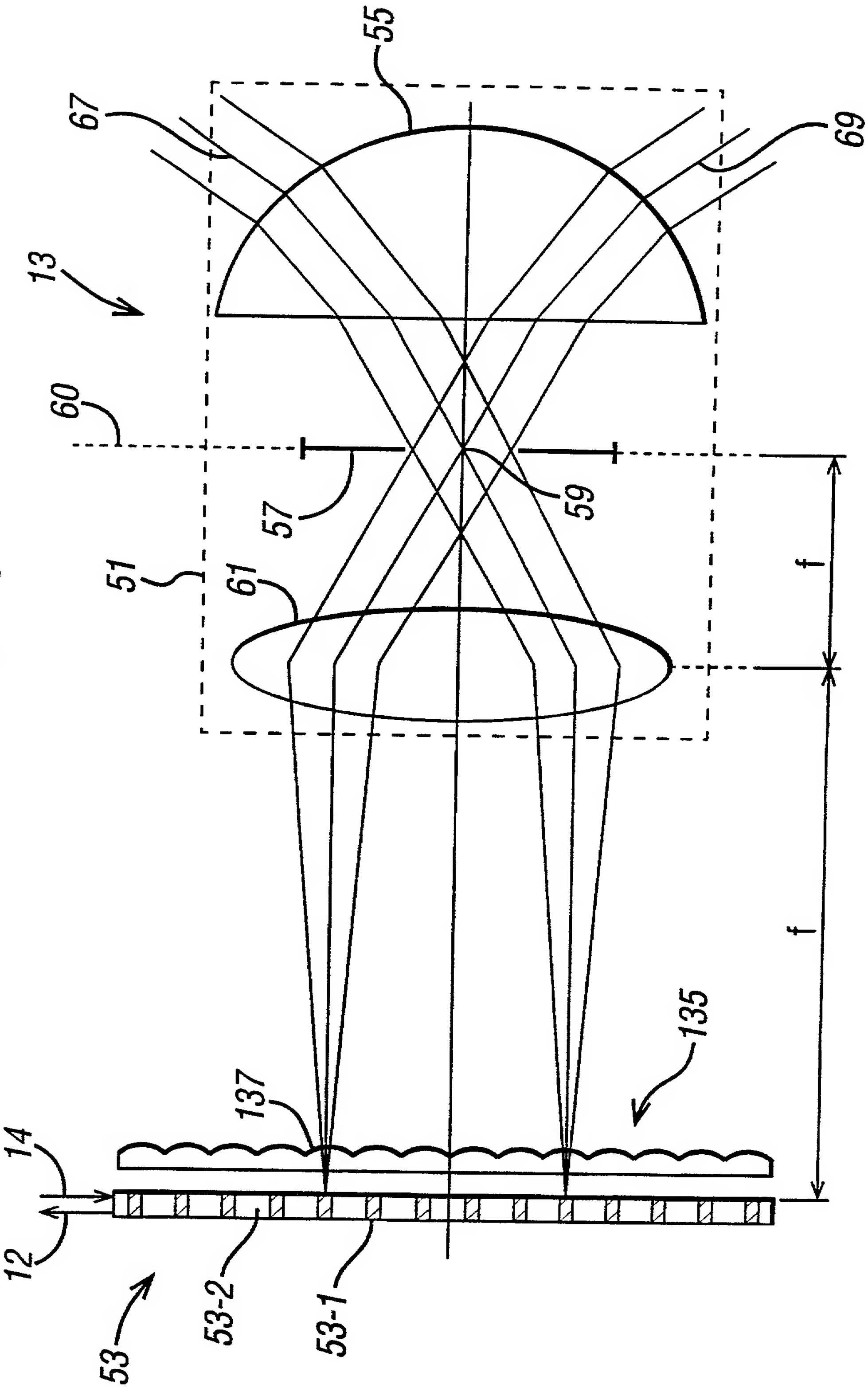
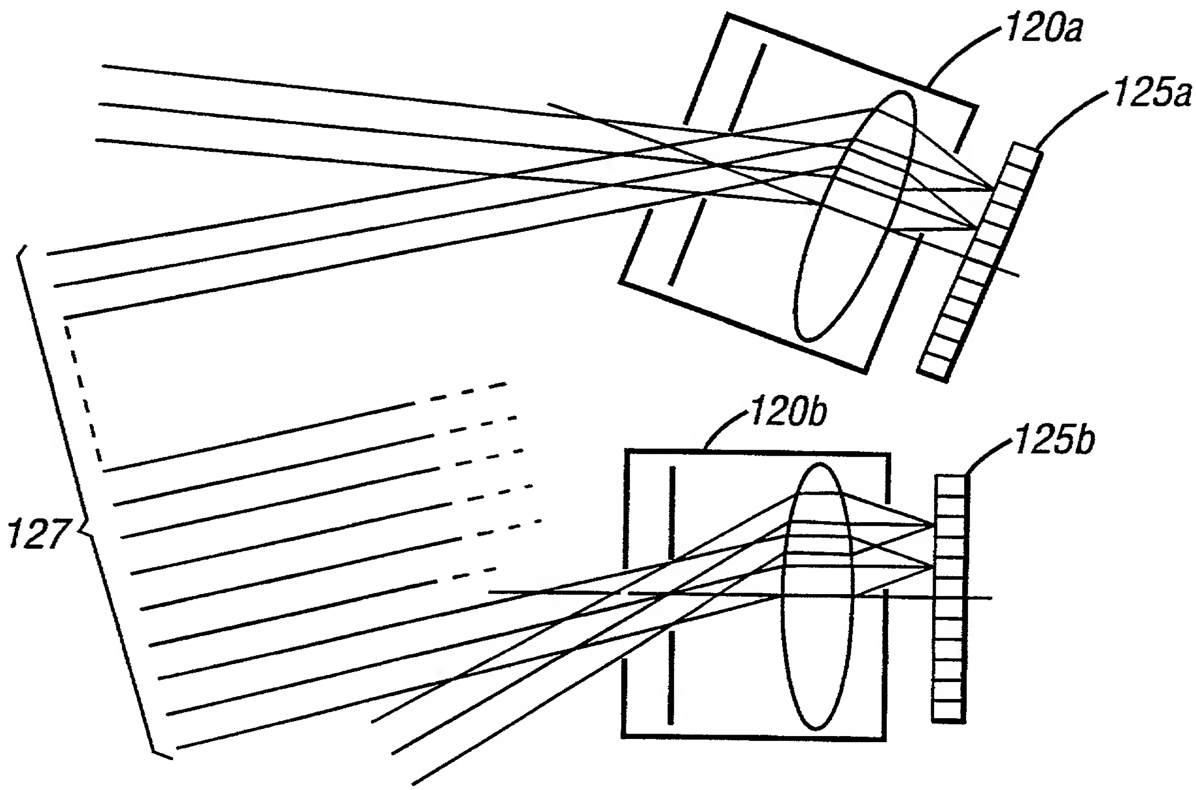


FIG. 16

FIG. 17



DECLARATION AND POWER OF ATTORNEY

As a below named inventor, I hereby declare that: my residence, post office address and citizenship are as stated below next to my name; I believe I am the original, first, and sole inventor (if only one name is listed below) or an original, first, and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

SIGNALLING SYSTEM

the specification of which
☐ is attached and/or
☒ was filed as United States Application Serial No. on January 8, 2002, and was amended on January 8, 2002 or
☒ PCT International Application No. PCT/GB00/02668, filed July 10, 2000, and was amended on September 3, 2001.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above. I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR § 1.56.

I hereby claim foreign priority benefits under 35 U.S.C. § 119(a)-(d) or § 365(b) of any foreign application(s) for patent or inventor's certificate or § 365(a) of any PCT international application(s) designating at least one country other than the United States, listed below and have also identified below, any foreign application(s) for patent or inventor's certificate, or any PCT International application(s) having a filing date before that of the application(s) of which priority is claimed:

Country	Application Number	Date of Filing	Priority Claimed Under 35 U.S.C. 119
Great Britain	9916080.6	July 8, 1999	☒ YES ☐ NO
Great Britain	9916422.0	July 13, 1999	☒ YES ☐ NO

I hereby claim the benefit under 35 U.S.C. § 119(e) of any United States provisional application(s) listed below:

Application Number	Date of Filing

I hereby claim the benefit under 35 U.S.C. § 120 of any United States application(s) or § 365(c) of any PCT International application(s) designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application(s) in the manner provided by the first paragraph of 35 U.S.C. § 112, I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR § 1.56 which became available between the filing date of the prior application(s) and the national or PCT International filing date of this application:

Application Number	Date of Filing	Status (Patented, Pending, Abandoned)

I hereby appoint the following attorney and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. **FINNEGAN, HENDERSON, FARABOW, GARRETT & DUNNER, L.L.P., CUSTOMER NUMBER 22,852,** Douglas B. Henderson, Reg. No. 20,291; Ford F. Farabow, Jr., Reg. No. 20,630; Arthur S. Garrett, Reg. No. 20,338; Donald R. Dunner, Reg. No. 19,073; Brian G. Brunsvold, Reg. No. 22,593; Tipton D. Jennings, IV, Reg. No. 20,645; Jerry D. Voight, Reg. No. 23,020; Laurence R. Hefter, Reg. No. 20,827; Kenneth E. Payne, Reg. No. 23,098; Herbert H. Mintz, Reg. No. 26,691; C. Larry O'Rourke, Reg. No. 26,014; Albert J. Santorelli, Reg. No. 22,610; Michael C. Elmer, Reg. No. 25,857; Richard H. Smith, Reg. No. 20,609; Stephen L. Peterson, Reg. No. 26,325; John M. Romary, Reg. No. 26,331; Bruce C. Zotter, Reg. No. 27,680; Dennis P. O'Reilley, Reg. No. 27,932; Allen M. Sokal, Reg. No. 26,695; Robert D. Bajefsky, Reg. No. 25,387; Richard L. Stroup, Reg. No. 28,478; David W. Hill, Reg. No. 28,220; Thomas L. Irving, Reg. No. 28,619; Charles E. Lipsey, Reg. No. 28,165; Thomas W. Winland, Reg. No. 27,605; Basil J. Lewris, Reg. No. 28,818; Martin I. Fuchs, Reg. No. 28,508; E. Robert Yoches, Reg. No. 30,120; Barry W. Graham, Reg. No. 29,924; Susan Haberman Griffen, Reg. No. 30,907; Richard B. Racine, Reg. No. 30,415; Thomas H. Jenkins, Reg. No. 30,857; Robert E. Converse, Jr., Reg. No. 27,432; Clair X. Mullen, Jr., Reg. No. 20,348; Christopher P. Foley, Reg. No. 31,354; John C. Paul, Reg. No. 30,413; Roger D. Taylor,

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Full Name of First Inventor	Inventor's Signature	Date
1-00 Alan Edward GREEN	A E Green	25/3/02
Residence Cambridgeshire, United Kingdom GBX		Citizenship Great Britain
Post Office Address QUANTUMBEAM LIMITED Abbey Barns Duxford Road, Ickleton Cambridgeshire CB10 1SX United Kingdom		

Full Name of Second Inventor	Inventor's Signature	Date
2-00 Euan MORRISON	E. Morrison	25/3/02
Residence Cambridgeshire, United Kingdom GBX		Citizenship Great Britain
Post Office Address QUANTUMBEAM LIMITED Abbey Barns Duxford Road, Ickleton Cambridgeshire CB10 1SX United Kingdom		

Full Name of Third Inventor	Inventor's Signature	Date
3-00 Michael REYNOLDS	M. Reynolds	26/3/02.
Residence Cambridgeshire, United Kingdom GBX		Citizenship Great Britain
Post Office Address QUANTUMBEAM LIMITED Abbey Barns Duxford Road, Ickleton Cambridgeshire CB10 1SX United Kingdom		